THE ARTIFICIAL SILK INDUSTRY AND INDIA

BY

BISHAN NARAIN, B.A., LL.B.

WITH A FOREWORD

BY

DR. SIR PRAFULLA CHANDRA RAY,
Kt., C.I.E., D.Sc., Ph.D., F.R.C.S., etc., etc.,
Dean of Faculty of Scienee,
Calcutta University.

WITH ILLUSTRATIONS.

DELHI.
ASSOCIATION FOR THE DEVELOPMENT OF SWADESHI INDUSTRIES,
CHANDNI CHOWK.

The
Artificial Silk Industry and India

Printed by M. P. MENON at the Metropolitan Press, Delhi,
and published by S. R. AGARWALA, Hony. Secretary, Association for the
Development of Swadeshi Industries, Chandni Chowk, Delhi.

FOREWORD

By Acharya Dr. Sir P. C. Ray, Kt., C.I.E., D.Sc. (Edin.), Ph.D. (Cal.), Dean of Faculty of Science, F.R.C.S. (Lond.), F.R.A.S. (Bengal), etc., etc.

The manufacture of artificial silk is a remarkable instance of the application of science to the needs of our daily use. Rayon is supplanting, slowly but surely, natural silk. England, Italy, and in the Far East, Japan, have already started gigantic industries for its manufacture. The districts of Murshidabad and Maldah could boast at one time of the flourishing Silk Industry and now it is threatened with extinction, thanks to its competition with the artificial product. I give below some of the statistics quoted by the author (p. 11): 414 lakhs in the year 1929-30 and the average of the last three years is valued at Rs. 391 lakhs. Of course, owing to trade depression of late years, the importation has slightly decreased.

India contains abundant raw materials for the manufacture of artificial silk and if capital, enterprise and expert knowledge could be mobilised, there is no reason why she should continue to be the dumping ground of foreign exploiters. Mr. Bishan Narain has done well in putting together in a handy form all the available information on the Artificial Silk Industries, and I trust his laudable efforts in this direction will be crowned with success.

:o:

4th September 1933.

UNIVERSITY COLLEGE OF SCIENCE & TECHNOLOGY,
DEPARTMENT OF CHEMISTRY,
CALCUTTA.

PREFACE.

For many years India has been the chief market for the industrial products of the world. The great majority of her population is dependent upon agriculture. Her overseas obligations are met by the export of her staple products. Her capitalists, with a few notable exceptions, have till very recently left the work—and the profits—of manufacturing her valuable raw materials to other nations. But during the last decade a slow change has come about in the angle of vision of her people, and there are signs of a great industrial awakening. Ever deepening shadows of agricultural depression by a persistent fall in the prices of her raw products; the abandonment of the Gold Standard, coupled with the linking of the Rupee with Sterling; a very considerable outflow to other countries of gold; the revival of the Swadeshi movement; the general trade depression; the ever increasing unemployment in the country; the increase of academic education in India: all these circumstances have combined in producing a keen desire in the country to develop her industries. Her people are now becoming alive to the great advantages to be derived from manufacturing her own raw materials, especially in view of the fact that she produces an abundance of such materials, with an ample potential supply of cheap labour and adequate sources of power. The capitalist who has hitherto been quite content with the 5 or 6 per cent. interest that he received on his deposits in the bank has lately received a rude shock on account of the inevitable fall in the rate of interest. And now he is on the lookout for more advantageous forms of investments, with the result that nowadays serious attempts are being made to carry on an intensive and extensive investigation into the unex-

plored avenues of industry. But owing to the lack of proper industrial and technical education, India has not been able to produce the type of mind which has a masterly grasp of industrial subjects.

Capital in India is not shy, as is clearly evident from the manner in which her three greatest manufacturing industries have been financed, namely, the textile, jute and sugar industries, the last named of which has developed mainly during the last two years. I am of opinion that the chief obstacle which prevents the capitalist from coming forward is the want of knowledge and confidence. The textile and jute industries have inspired the capitalist with confidence by the eflux of time, and the protection of the sugar industry has given him a sense of security, and all is well so far as it goes.

But the industrial system in India is unevenly, and in most cases inadequately, developed. In comparison with other countries, the industrial development of India has not been commensurate with the size, the population, and the natural resources of the country. The economic welfare of a country like India, which depends to so great an extent as she does on agriculture, is unstable. Therefore I have no hesitation in saying that the development of industries in India would be to the greatest advantage of the country, for this would create new sources of wealth, encourage the accumulation of capital, promote profitable employment for labour, reduce excessive dependence of the country on the unstable profits of agriculture, and finally it would stimulate national life and develop the national character. A country where industries are undeveloped tends to be inflicted by a certain intellectual deadness, because the outlets for diversity of talents are few and initiative is strangled at its source.

This work which I am presenting to the people of India has been designed with these objects and ideals in view. It is not intended to be a work of science, although I have given a brief description of the chemistry of Artificial Silk, and for those who desire to go deeper into the subject, some details of the manufacturing processes are also given in smaller type; I have refrained from entering into a detailed examination of intricate chemical formulas and reactions. My object is to give some idea to the reader as to the nature of this industry, so as to enable him to come to some sort of definite conclusion. In this little book I have tried to prove that the Artificial Silk Industry affords a secure investment for the capitalist, and that it is one of those industries which have very good prospects. I would even go to the extent of saying that the Artificial Silk Industry has better prospects than many others that are in existence in this country. At present there is not a single factory of the kind in the country. It undoubtedly has a bright future before it, because it has a very strong hold on the popular fancy, which is evident from the fact that, in spite of the great political agitation in the country in 1930-31, when most of the mills in Bombay and Ahmedabad discontinued its use, and when the imports of all other textile materials fell considerably, there was very little depreciation in the quantity of artificial silk imported into India. The Bombay takings fell by 270,000 lbs, but at the same time those of Madras increased by 214,000 lbs., to feed the handloom industry in Southern India. Thus there was practically no decrease in the quantity of the artificial silk cloths imported from Japan and other countries, and since then the imports have again increased, and that beyond the figures prior to 1930, and when artificial silk is made in India, a still further big increase in its consumption is a foregone conclusion. This fact should

create a sense of permanence for the industry, and of security to the capitalist.

During the last three years I have made extensive enquiries into this subject, and I have noted down the results I have arrived at for the benefit of our people. I am open to correspondence on the subject with those who feel a genuine interest in the matter. The subject dealt with is vast and highly technical, and the task which I have been set is no easy one, so that should the performance occasionally fall short of my ideal, or of the critical reader's expectations, the latter is asked to consider the words of Goethe that "higher aims, even if unfulfilled, are in themselves more than lower aims quite attained."

In conclusion, I should like to express my thanks to Messrs. Ateliers Mecaniques de Courbevoie who have supplied plates, blocks and photographs of machines, together with technical information. I am also indebted to Mr. G. J. Piper for the valuable assistance he has rendered me in revising this little work.

BISHAN NARAIN,
Hony. Genl. Secy.,
ASSOCIATION FOR THE DEVELOPMENT OF
SWADESHI INDUSTRIES, DELHI.

Delhi, 1st August 1933.

TABLE OF CONTENTS.

THE ARTIFICIAL SILK INDUSTRY AND INDIA

CHAPTER I.

INTRODUCTORY AND HISTORICAL.

ARTIFICIAL silk as a material for weaving has acquired great commercial importance during the past few years, and the reasons for this are not far to seek. Artificial silk has been put to very many practical uses, and various articles of daily use, such as cloth, hosiery, ribbons, laces, etc., are extensively made from it. Thus this scientific discovery has, by virtue of its low price, placed many beautiful useful and fancy articles within the reach of the poor and those with limited incomes who cannot afford real silk, and by its brilliancy and beauty it has completely captured the popular fancy.

Full particulars as to the uses to which artificial silk is being put are not readily available, but the following statement will be found interesting as indicating the diverse uses to which it is being put to-day in England, U. S. A. and Germany.

Percentage of Artificial Silk used in different industries.

	U. K.	U. S. A.			GERMANY.
	1925	1914	1925	1928	1926
Hosiery		47	28	18	
Underwear	40	...	...	33	46
Knitted goods (except hosiery)		3	5	4	
Interwoven with cotton ...		14	26	20	20
Interwoven with silk ...	25	12	16	13	16
Interwoven with wool ...		2	1	0·5	
Interwoven with linen ...	...	...	13	...	
Plush	...	15	1	1·5	
Tapestry	...	2	...	1·0	
Ribbons, braids, ties, etc. ...	30	3	4	6	18
Elastic webbing	1·5	...	...	...	
Cords	2·5	...	...	...	
Miscellaneous	1	2	6	3	

Such figures naturally vary from year to year, according to the demands of fashion, and as new ways are found of working up the different yarns and combining them with other fibres. Rapid and constant progress is being made in the latter direction.

The following brief survey of the chief uses of artificial silk will show the part it has come to play in modern life.

Hosiery.

In recent years there has been a marked tendency in feminine fashions towards the use of bright and lustrous materials such as silk. For a time this tendency was retarded by the high cost of real silk; but with the introduction of artificial silk for hosiery and haberdashery, such articles came within the reach of the majority of people in practically every country in the world.

When artificial silk was first used for hosiery, it was found to have certain drawbacks, such as "laddering", which was partly due to its lack of elasticity and sensitiveness to moisture and friction. Further, its excessive lustre was considered too showy. Now, however, processes are in use whereby the lustre can be suitably modified to suit the purpose for which it is required as well as the taste of the wearer. The finer filament yarns are at present extensively used for hosiery, and although for this purpose pure artificial silk is generally used, a stronger material is obtained by "plaiting" the article on cotton or cashmere. This has also the advantage, in colder climates, of being warmer for wear.

Knitted Goods.

Besides hosiery, there are very large quantities of knitted fabrics now being produced from artificial silk, such as stockinette, Milanese fabrics and fricots, which are made into dresses, underwear, ties, etc. The pro-

duction of fine denier yarns and improved methods of knitting them have largely helped in this respect.

The application of artficial silk to the production of laces and curtains has also been developing, and very fine effects can be produced in such goods as bedspreads, chair-backs, cushion covers, duchesse sets and fancy table cloths, and artificial silk has very largely replaced cotton in the manufacture of elastic webs and braids. Moreover, the use of cellulose-acetate artificial silk in combination with other artificial silks has enabled diverse colour effects to be produced, owing to the difference in their dyeing properties.

Artificial Silk and Cotton.

Although artificial silk is mainly used in the manufacture of the products mentioned in the preceding paragraphs, a mixture with cotton or other fibres may be utilized where strength or contrast effects are desired. There is now a very wide range in woven fabrics of cotton artificial silk, which may contain percentages of artificial silk ranging from 5 to 6. Thus we have cotton coatings, Bedford cords, cambric shirtings, lingerie fabrics, cotton marocains, poplins, sateens, blouse and dress fabrics, voiles, mock voiles, and many others too numerous to mention.

Artificial silk velvets also are now being produced very successfully, and these have the advantage of lightness and better draping properties than silk velvets. Moreover they are said to mark and crease less.

Artificial Silk and Wool.

The lustre, brightness and sheen of artificial silk enable it to supplement the properties of wool, such as warmth, curl and roughness of the fibre, so that many mixtures of these two fibres enable fabrics to be produced which have advantages over both. Covert coatings, gabardines, linings and special cloths for India

and other eastern countries are being made in increasing quantities. With the advance in knowledge of the dyeing properties of artificial silk, more ambitious designs, so as to produce maximum effects, are being turned out.

Artificial Silk and Silk.

More satisfactory results are being attained by mixing the fine-denier artificial silk yarns with real silk and such mixed fabrics are being produced with pleasing effects. Thus, for instance, crépe-de-chines are being made from natural silk and cellulose-acetate artificial silk combined.

Artificial Silk and Linen.

At first there were technical difficulties in combining artificial silk with linen, but these have now largely been overcome, and table linen made from these two fibres have proved very attractive and successful. The lustre of the former enhances the pattern effects.

Artificial Silk Cloths.

Recent developments have shown that artificial silk cloth can be produced in weaves hitherto possible only in real silk, *e. g.*, crépe-de-chine, marocain, foulard, jap, taffeta, satin and surah.

Miscellaneous Uses.

Incandescent gas mantles and insulating materials in the electrical industry have also been made from artificial silk with success.

The above cursory review of the uses of artificial silk has achieved its purpose if it indicates the enormous possibilities that lie in store for the Artificial Silk Industry in India, and it goes without saying that industry in India, and India in general, would be tremendously benefited by the introduction into India of the manufacture of artificial silk.

The idea of producing artificial silk was put forward as early as 1665 in Hooke's "Micrographia," where it was pointed out that "there might be a way found out to make an artificial glutinous composition much resembling, if not full as good as, nay better than, the excrement or whatever other substance it be, out of which the worm wiredraws his glue." Again in 1734 a simlar suggestion was put forward by the naturalist de Réaumur in an account of the silkworm. In 1740 a Frenchman named Bon actually produced some yarn made from the filament of spiders' webs and made with it stockings and gloves. In 1770 another Frenchman named Dubet made experiments and produced filaments from the silky gum extracted from dead silkworms. In 1842 an English silk manufacturer named Schwabe, in a paper read before the Manchester meeting of the British Association, put out some suggestions to the effect that certain solutions when pressed through fine holes would produce filaments like those of silk. In 1850 John Mercer, the well-known London calico printer, observed the action of caustic alkalies on the cotton fibre, and the product thus obtained has long been known as mercerised cotton.

The first method employed for the manufacture of artificial silk was based on the already well known properties of nitro-cellulose. This process was employed in the manufacture of explosives Audemars of Lausanne, in 1885, took out the first English patent and produced artificial silk from a solution of nitro-cellulose in an alcohol-ether mixture, and with the help of a steel pointer he drew out threads from it and reeled them.

In 1883, when electricity was employed for lighting purposes, the research for proper filaments which could readily be carbonised led to further developments in the production of artificial silk. Swann, who took

out a patent for producing filaments from nitro-cellulose solution for electric lamps, recognised that such filaments could be used for producing artificial silk, and in 1884 and 1885 he exhibited some samples of it in London.

Count H. De Chardonnet in France was also engaged in making experiments in the producing of artificial silk filaments from nitro-cellulose solutions. In 1884 an account of his work was presented to the Academie des Sciences, and patents were taken out in 1885. Cloth woven from artificial silk was exhibited for the first time at the Paris Exhibition of 1889.

That time marks the beginning of the production of artificial silk by nitro-cellulose process, and the industry was established on a manufacturing basis in France, Switzerland, Germany and other countries.

In 1890 Despeissis and certain other inventors made experiments with cuprammonium solutions of cellulose for the production of artificial silk, and in 1897 Pauly adopted this processs and employed it in manufacture on a commercial basis. By virtue of the constant experiments and exertions of Urban, Fremery and Bronnert, many difficulties were overcome and thus the manufacture of artificial silk by the cuprammonium process became firmly established in France, Germany and Belgium.

While the two processes mentioned above were struggling to come to the fore, Cross, Bavan, and Beadle, the wellknown authorities of the Department of Applied Chemistry, while working on cellulose in 1891, discovered that alkaline cellulose reacted with carbon bisulphide to form a compound soluble in water which was named "Viscose." The importance of the viscose process for the production of artificial silk was not realized at the time, but afterwards it went far ahead of the other processes and soon it was developed to its present pitch of perfection and degree of success.

Yet another process, which has aroused considerable interest, is based on the spinning of cellulose-acetate filaments. Cellulose acetate was first prepared in 1869 by Schutzenberger and Naudin, but it is only recently that some measure of success has been achieved in the production of artificial silk by this process, and that owing to the inventions of H. Dreyfus.

The following four processes are the only ones used for producing artificial silk commercially, *viz* :—

(1) The Viscose Process (see Chapter III).

(2) Cellulose Acetate Process (see Chapter V).

(3) The Cuprammonium Process (see Chapter VI).

(4) The Nitro-cellulose or Collodion Process (see Chapter VII).

The world's production in each of these processes for the years 1928 to 1930 has been as follows (in thousands of pounds) :—

	1928	1929	1930
	lbs	lbs	lbs
Viscose Silk	293,320	324,625	322,800
Acetate Silk	25,100	37,750	32,000
Cuprammônium Silk	13,950	18,800	15,000
Collodion Silk	13,030	13,950	9,000
Other Processes	2,000	2,000	1,500

From the above table, it follows —

(*a*) That the Viscose process represents about 80 per cent. of the world's production, and that this percentage tends to increase ;

(*b*) That the Acetate process represents about 10 per cent. and shows only slow progress ;

(*c*) That the Cuprammonium process reaches only 5 per cent. and is decreasing; and

(*d*) That the Collodion process, which represents 5 per cent , has now completely ceased.

A comparison of these different processes shows that the exceedingly great development of the viscose method of manufacture is due to the following factors.

The viscose process is much more economical, and by it the production of artificial silk is less costly.

In the acetate process the raw materials are very much more costly and the solvents are recuperated with great difficulty. The waste is also considerable, the adjusting of this process being much longer and more delicate and the chemical side of other celluloses being extremely complex.

The stability of certain acetate silks is not so satisfactory for use where silk of the finer qualities is more easily employed, especially for furniture materials, for these silks fall to dust after some years; and also when used for undergarments, where the decomposition of the acetate attacks the skin and causes irritation.

It is estimated that the world's production of artificial silk in the first quarter of 1931 amounted to 97.5 million pounds. The total production during the year 1929 amounted to 434.9 million pounds, and that of 1930 was 410.7 million pounds. The following table gives the details as to countries :—

(In millions of pounds)

	1928	1929	1930
United Kingdom	50.4	52.4	48.8
Canada	3.5	4.4	5.4
Germany	52.50	55.1	57.8
Holland	18.0	20.0	15.8
Belgium	15.0	14.0	10.4
France	30.0	37.0	39.2

	1928	1929	1930
Italy	57.3	71.3	59.7
Switzerland	12.0	12.2	9.7
Austria	4.0	8.6	1.4
Poland	5.0	5.4	5.3
Czechoslovakia	3.5	4.2	4.4
Other European Countries	3.8	3.4	4.5
Japan	14.4	30.8	33.3
United States	115.0	121.1	97.5
World's Total	367.3	434.9	410.7

There has been a phenomenal increase in the world's production of artificial silk within the last 35 years, and the increase since the war has been very much more rapid than previously. This is clearly evident from the following table.

World's Output of Artificial Silk.

Year.	Metric Tons.
1896	600
1900	1,000
1901	1,500
1902	2,500
1903	3,000
1904	4,000
1905	5,000
1906	6,000
1907	6,500
1908	7,000
1909	7,500
1910	8,000
1911	8,500
1912	9,000
1913	11,000

Year.			Metric Tons.
1914	....	....	12,000
1915	....	....	13,500
1916	....	....	15,000
1917	....	....	15,500
1918	....	....	16,000
1919	....	....	20,000
1920	....	....	25,000
1921	....	....	30,000
1922	....	....	35,500
1923	....	....	47,500
1924	....	....	64,000
1925	....	....	85,500
1926	....	....	99,500
1927	....	....	121,300
1928	....	....	158,000
1929	....	....	184,100

(One Metric Ton=2204.6 lbs).

CHAPTER II.

ARTIFICIAL SILK IN INDIA.

INDIA, with her one fifth of the population of the world, is a country large enough to be called a continent; and she occupies a very prominent place amongst the consumers of artificial silk, and yet she does not produce it—a fact that should set our industrialists thinking.

The following table shows the Indian imports of artificial silk in the shape of yarn and cloth from 1923 to 1931.

Year.	Artificial Silk Yarn. lbs.	Artificial Silk Cloth. Yards.
1923-24	406,000	8,555,000
1924-25	1,171,000	17,020,000
1925-26	2,671,000	15,362,000
1926-27	5,776,000	41,978,000
1927-28	7,510,000	53,141,000
1928-29	7,668,000	49,801,000
1929-30	7,353,000	56,600,000
1930-31	7,119,000	51,495,000

In the year 1928-29 the total value of the artificial silk yarn and cloth imported into India was 465 lakhs of rupees, while in the year 1929-30 the total value was 414 lakhs and during the year 1930-31 it was 239 lakhs. There has been no appreciable decrease in the quantity of artificial silk imported, but the price has gone down considerably on account of the keen Japanese competition. India has on an average during the last three years consumed 15,176 million pounds per year, at an average value of Rs. 391 lakhs. The decrease in the quantity imported during 1930-31 was due to the disturbed political condition of India in that year.

Out of the average world production of 404.3 million pounds, India has consumed 15.176 million pounds, excluding various other articles of artificial silk, such as socks, underwear, ties, kerchiefs, etc. Italy and Japan have contributed the largest share of the artificial silk yarn and piece goods imported into India.

CHAPTER III.

ARTIFICIAL SILK—ITS CHEMISTRY AND MANUFACTURING PROCESSES.

I. General Outline of its Chemistry.

THE artificial silk product is extracted from vegetable fibre and cellulose by a chemical process. All plants in their earlier stages are composed of cells—a cell is a minute membranous bag, round like a ball, without any mouth or opening. As the plant reaches a more advanced stage of development, these cells undergo a change in form. Many of them assume elongated shapes, becoming tubes with tapering extremities. The whole of the vegetation consists of such minute hollow elements closely packed together, forming the tissues of a plant. The soft parts, such as leaves, flowers and fruits, are composed of more or less rounded cells, while the wood and veins of leaves and other hard parts are composed of fibres. These cells and fibres contain a solution which is composed of gum, sugar, and albuminous and solvent matter, together with solid deposits of starch, green colouring matter, crystalline solids and resinous incrustations.

When a mass of vegetable tissue, say sawdust, is boiled in water with caustic soda and other solvents, there remains a mass of colourless, odourless and tasteless substance which is composed of membranes, and which forms the walls of the cell or cellulose.

In cotton the cellulose is found in a nearly pure form. Cotton, when examined under the microscope, is seen to consist of long fibres more or less flattened and twisted.

Cotton wool, duly washed and purified, may be regarded as normal cellulose. It is not soluble in all ordinary neutral solvents; there are, however, liquids in which cellulose is dissolved without an obvious change of composition. By an appropriate process this solution of cellulose is turned into the from of a gelatinous mass, which is called VISCOSE. Viscose is forced through fine jets into diluted sulphuric acid, when it again assumes the form of solid cellulose. The threads of cellulose thus produced are then spun to form "Artificial Silk", technically called "Rayon Yarn". The lustre of this product is greater than that of natural silk. In the dyebath it takes up colouring matter freely. There is only one defect, and that is it loses considerable strength when it is wet, but it recovers it again on drying, and by immersion in a solution of formaldehyde the fibres are further strengthened. A full chapter of this book is devoted to a more detailed description of the chemical process employed in the formation of artificial silk.

Cellulose is found in nature as a constituent of cotton (87 to 91%), woods (60%), and straws (35%). From the technological point of view cotton and wood are the most important sources of cellulose for the manufacture of artificial silk at the present day. It is not possible in a work of this kind to describe in detail every process, or modification of a process, for making artificial silk and to discuss in detail the chemical reaction involved in the preparation of this viscose, as every process has been patented from time to time.

The manufacture of viscose silk comprises the following operations:—

(1) Preparation of the raw materials.
(2) Preparation of the Viscose.
(3) Spinning.
(4) Finishing off.

These stages and the operations entailed are dealt with *seriatim* below.

(1) Preparation of the Raw Materials.

Viscose Process.—At present cotton and wood are the only substances that can be taken into practical consideration as sources of cellulose for the manufacture of viscose. The possibility, however, of utilising other sources of cellulose has been explored. Flax, bagasse (sugar-cane residue) and similar materials have been converted into pulp which on analysis compares favourably with the standard usually required of wood pulp used in the viscose manufacture. The yields of pulp from such raw materials are low in some cases, and special treatment has to be applied to reduce the ash contents.

Cotton in the form of spinning waste and linters (short cotton fibre unspun) can be utilised, but its use for viscose has been found very expensive, because the countries where the manufacture of artificial silk is carried on are not cotton growing countries, and there wood is a much cheaper raw material. Cotton has, however, an advantage, in that the artificial silk produced from it has at least 25 per cent greater tensile strength than that produced from wood. Cotton, before it can be used, has to be freed from oil, fat, wax and colouring matter by means of extraction with organic solvents, boiling under slight pressure with weak alkalies, scouring and bleaching. The purified material, after drying and teasing out, is ready for use, or may be pulped and converted into sheets, in which form it can be more easily handled.

Wood pulp is generally employed, because in the countries where artificial silk is manufactured it is the cheapest material. Trees, generally pine, are cut up and the chips thus produced are cooked for twentyfour hours in recipients filled with a solution of bisulphite of lime. The resultant pulp, thoroughly washed in pure water, is then strained, and after a last washing it is bleached with hypochlorite of lime. The bleached cellulose is washed on sifters and made up into sheets of a fixed size by being pressed between rollers. In this process an abundant supply of pure water is necessary.

(2) Preparation of the Viscose.

Messrs. CROSS & BEVAN prepared the viscose in the first place by dissolving, in a solution of caustic soda, the xanthate which they had obtained by the reaction of the carbon disulphide on the cellulose impregnated with caustic soda.

Stern proved the necessity of the ripenings which brought about important changes in the properties of the viscose.

The preparation of the viscose consists of—

A. The preparation of the alkali cellulose.
B. The preparation of the cellulose xanthate.
C. The mixing and disolution of the xanthate,
D. The filtrations and ripening of the viscose.

A.—Preparation of the Alkali Cellulose.

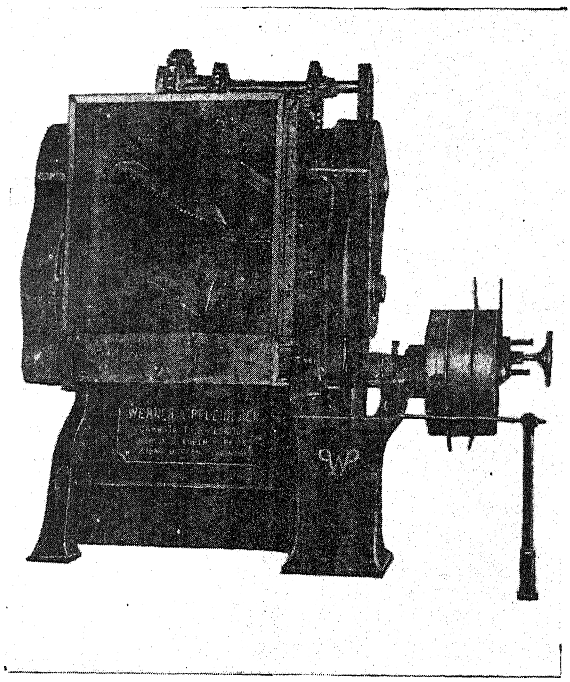
The sheets of cellulose pulp are dried in a room or a tunnel at a constant temperature so as to make their humidity consistent and uniform throughout. They are next steeped in a bath of caustic soda; then the superfluous caustic soda is eliminated by pressure. The steeping was formerly done in iron tanks, but nowadays steeping presses, which reduce the manipulation, are in use practically everywhere. These steeping presses are driven either mechanically or by hydropower. The steeping is often done at about 20 degrees Centigrade and for an hour's duration; but this will vary with the factory.

The alkali cellulose thus obtained is broken up and reduced to powder by means of grinding stones or by kneaders. The flaky mass resulting from the kneading is then put into iron boxes and left for a fixed time in a constant temperature. This is the first ripening, and as a rule it lasts about sixty hours under a constant temperature of 24 degrees Centigrade.

B.—Preparation of the Cellulose Xanthate.

After ripening, the alkali cellulose is treated with carbon disulphide. This operation takes place in churns with a double envelope so formed as to allow for the circulation of cold or warm water with a view to maintaining the temperature at the required

PLATE I.

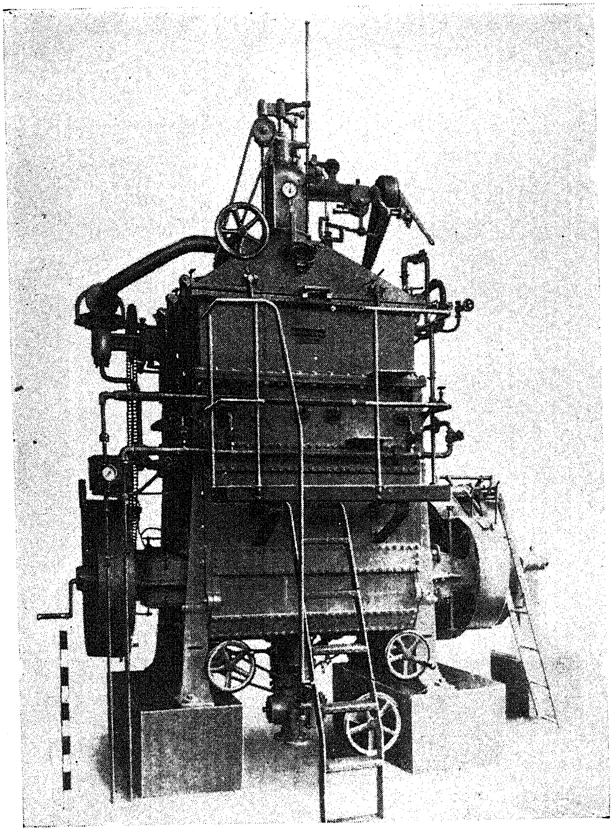


Kneading Machine for Alkali-Cellulose.

(Ateliers Mecaniques de Courbevoie).

To face page 16.

PLATE II.



Vacuum.

(Ateliers Mecaniques de Courbevoie).

To face page 17.

degree. Cold or warm water is used according to the season. The temperature should vary from 18 to 20 degrees C. at the beginning of the operation and from 25 to 27 degrees C. at the end of the operation. It is determined by the orange red colour of the balls of cellulose xanthate. The carbon disulphide employed being very volatile and inflammable, the greatest care must be exercised in handling the same.

C.—Mixing and Dissolution of the Xanthate.

As has already been said, the viscose is obtained by the dissolution of the xanthate in a light concentration of caustic soda. This operation takes place in mixers which are either vertical or horizontal. A system of fixed and mobile plates energetically stirs up the mixture, breaking up the balls of xanthate and thus facilitating the dissolution. The duration of the dissolution is about three hours in a horizontal mixer.

The preparation of the cellulose xanthate and its dissolution can also be carried out in a single machine, called a vacuum. This system is favoured to-day, because it simplifies both the material and the labour.

D.—Filtration and Ripening of the Viscose.

The viscose, having been placed in containers, is left for a determined time in a room at a constant temperature. This ripening modifies the viscosity and the aptitude of the viscose towards coagulation. This coagulation increases according to the degree of ripening.

To ensure slow ripening of the viscose, some sulphite of soda is added during the mixing. In this way the stability of the viscose is prolonged. By increasing the temperature of the ripening room one can accelerate the ripening, but this will reduce the period of stability during which the viscose can be used in the spinning rooms.

During the ripening the viscose is filtered several times, to eliminate any impurities that it may contain. For this operation filter presses are made entirely of iron, and with frames and plates.

Finally the viscose is cleared of all air by being subjected for some hours to a strong vacuum.

The viscose, having been filtered, arrives at last in the spinning room.

(3) Spinning of the Viscose.

In principle, the viscose is driven through a jet into a coagulating bath. The thread thus formed is drawn by a bobbin or by a godet. The regularity of the thread thus obtained depends on the consistency of the quantity of viscose coming from the jet and the regularity of the speed at which the thread is wound on to the bobbins or godets.

The spinning of the viscose is operated in two different ways, namely—

By parallel spinning on to bobbins, and

By centrifugal spinning into Topham pots.

A certain part of the spinning machine is common to both of these methods. They are:—

(a) The spinning pumps, and

(b) The filters and jets.

(a) The Spinning Pumps.

As the jets offer different degrees of resistance to the viscose in its passage through them, it has not been found satisfactory to feed them from a collector under constant pressure, for in this case the quantities given out by these jets are not uniform and the threads are irregular. Therefore, it has become necessary to feed such jets from a distributing organism, the spinning pump, whose role is to give the jets a constant quantity of viscose, whatever

---

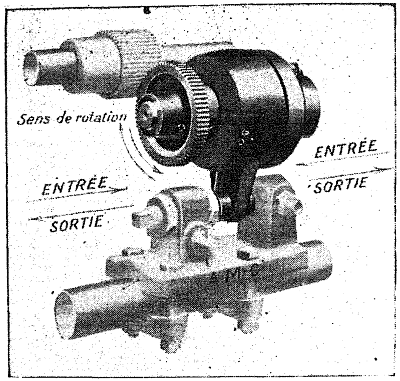
Definition of terms in current use.

"The standard of a thread," expressed in deniers, is given by the weight in grammes of 9,000 meters of this thread For example, a thread of 100 deniers weighs 100 grammes per 9,000 meters.

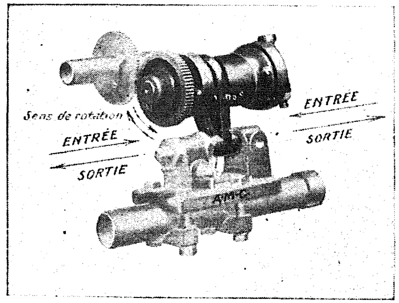
In order to determine the deniers, hanks from 450 meters in length are employed.

"The twist of a thread" is expressed in turns per meter. It can either be a right or a left twist. A thread has a right twist if, when held vertically at eye level, the coils are inclined at the bottom towards the right, and, it is a left twist if the inclination at the bottom is to the left.

PLATE III.



Spinning Pump, 5 Pistons.
Radial System.

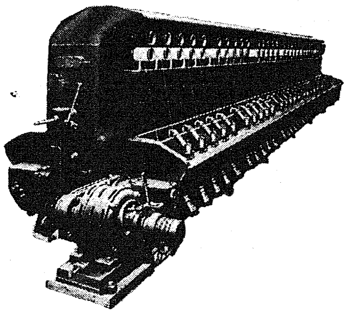


Spinning Pump, 3 Pistons.
Aerial System.

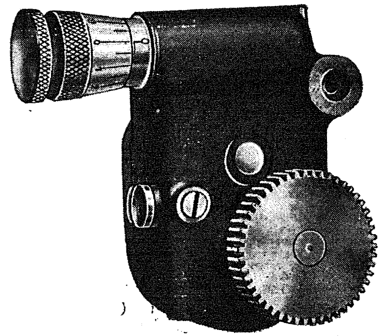
(Ateliers Mecaniques de Courbevoie).

To face page 18.

PLATE IV.



Spinning Machine, for
Small Bobbins.



Gear Pump.

(Ateliers Mecaniques de Courbevoie).

To face page 19.

may be the variations of pressure in the viscose collectors, or whatever the resistance in its passage through the jet. The pumps utilised are of different types, namely:—

(*i*) Alternative piston pumps, and
(*ii*) Gear pumps.

(*i*) *Piston Pumps.*[1]—Piston pumps with a single piston are no longer in use, and the present-day tendency is to multiply the number of pistons in order to regulate the output. The pumps that give the greatest precision from this point of view are those with 3 or 5 pistons.

(*ii*) *Gear Pumps.*[2]—The gear pumps, in principle, resemble those used for the circulation of oil, or for dealing with viscous matter. In theory these are simpler than the piston pumps and the curve of their immediate output is very near the straight line. But in practice there is a great difference in output. Its output is very high, but this kind of pump can only be recommended when the viscosity of the spinning liquid is regular and the pressure and counter-pressure on ejection from jets is absolutely constant. Even under these conditions it is necessary to verify the output. These pumps require frequent adjustment.

Both kinds of pumps have their utility, and they are actually in use, but the tendency now is to employ the multiple piston pumps in preference to the gear pumps. The latter are less costly but they wear out more quickly, and they often leak and are influenced by the variation of the viscosity and by pressure. The life of the gear pump is less than a year.

The multiple piston pumps are more costly and last much longer. They are generally used in France, England,

---

1 The ATELIERS MECANIQUES DE COURBEVOIE manufacture some very interesting pumps with 3 and 5 pistons, and these pumps are in use widely in the viscose factories throughout the world.

2 The ATELIERS MECANIQUES DE COURBEVOIE manufacture gear pumps, and they have studied the question of the reduction of these inconveniences. In this they have succeeded by using first class raw materials, which have been machined with all the precision that characterises all their manufactures, and by providing an easy adjustment for counteracting the play due to wear. This is effected by fixing to the bearings, by means of a regulating screw, an extra covering made from a special metal alloy. A special arrangement, moreover, allows of the control of the output by means of a screw, the head of which is milled and graduated.

Belgium, Switzerland, Spain and North America, and gear pumps are in use in Holland, Germany and Italy.

(*b*) *The Spinning Filters.*[1]

Before the viscose arrives at the jet, it is necessary to filter it. This filtering is effected in ebonite candle filters. The viscose, driven by the pump, is admitted into the filter and passes through a filtering mattress made from a band of fine cloth wound round the candle. The viscose thus filtered goes then to the jet. These candle filters[2] get blocked up very quickly and must be frequently cleaned out, great care being taken in the replacement of the fine cloth. In most of these filters the viscose filters from the inside towards the outside.

II. **Jets.**

In the making of viscose silk, jets with multiple and closely bored holes are used. The filaments solidify almost instantaneously in the bath and have no tendency to attach themselves one to another. These jets are made in the form of a disc perforated by holes of small diameter (one tenth of a millimeter). They must be made of a material which can resist alkalis and acids, be easily perforated and easily cleaned. The materials used are alloys of precious metals, alloys of platinum and irridium, gold and palladium, platinum, gold, palladium, or else porcelaine, glass, or steatite.

Jets of metal are most frequently used. To clean them, they are immersed in a bath which destroys the organic matter (sulphuric acid and bichromate), then rinsed in distilled water. The condition of the jet holes is verified by means of a projecting lamp. The jets are mounted in jet carriers of ebonite, bakelite, or an alloy of lead, tin and antimony.

---

1 The A. M. Spinning Machine Filters can be looked after and cleaned without stopping the machine. With this filter one can work at will either from the interior towards the exterior of the filter candles or *vice versa*. This is an important advantage, for certain solutions that are thicker than others adapt themselves better to the distension of the cloth under pressure from the inside.

2 The ATELIERS MECANIQUES DE COURBEVOIE also make single candle filters which can be added to the filters at the head of the machine. In that case they play only a secondary role and need only be seen to at intervals.

When it leaves the jet, the diameter of the filament is too great. It is reduced by being drawn over a bobbin or a godet. The drag stretches the thread from its leaving the jet until its coagulation is complete. This corresponds to the action of the silk worm, which in its own way causes a drag by constant movements from side to side of its head, which movement acts on the thread from the time of its emergence. By this drawing of the thread one can fashion threads as fine as, and finer than, those of natural silk (one or two hundreths of a millimeter per single filament) by means of jets, the holes in which can be up to one tenth of a millimeter.

III. **Parallel Spinning on Bobbins.**

There are so far only two methods of parallel spinning in existence, namely—

(1) Spinning on small bobbins placed perpendicular to the shaft of the machine, and

(2) Spinning on large bobbins placed parallel to the shaft of the machine.

(1) Spinning on Small Bobbins.

This machine is made with double faced sections with the number of jets varying according to the type.

The mechanism, commanding the movements of the spinning pumps, is concentrated at one of the ends of the machine. In order to obtain a regular thread, it is necessary that the output from the jets should be constant and the speed of the winding thread on the bobbins uniform. There should be a device to prevent the thread from unwinding. This is ensured by diminishing the course of the back and forth movement as the winding is effected, by means of a cam of appropriate form. This movement should remain constant. On these machines the number of bobbins corresponds to the number of jets so that when one bobbin is being filled the other is in reserve. The change from one to the other is done either by hand or automatically. If the automatic movement is employed, the spinner's work is reduced and he can utilise the time so saved in removing the full bobbins and replacing them with empty ones, without stopping the machine. The bobbins employed should be so constructed as to resist acid attacks, and should be strong enough

to resist the effects of the removal of the thread during the drying process. They must be pierced with holes to allow the thread to be washed on the bobbins. They are made of paper bakelised, bakelite or alluminium bakelised. They are usually 150 mm. long and 90 mm. in diameter.

(2) *Parallel Spinning on Large Bobbins.**

Parallel spinning on big bobbins is based on the same principle as the spinning on small bobbins, and it only differs in this respect that the bobbins are placed parallel to the shaft of the machine and the dimensions of the bobbins are 160 mm. in diameter and 180 to 200 mm. in length. They are made of glass or reinforced bakelite. In parallel spinning machines all parts come into contact with liquid acids, or are likely to be splashed by these liquids, therefore the lead and the shafts must have their ends protected with leaden coverings.

IV. **Centrifugal Spinning.***

The characteristic of centrifugal spinning is the twist which is given to the thread as soon as it is congealed. The consistency of the thread is thus increased and there is less waste. In spite of the high cost of centrifugal spinning machinery, it is largely used on account of the economy in labour that it ensures, and the facility it gives for obtaining a thread of extreme fineness.

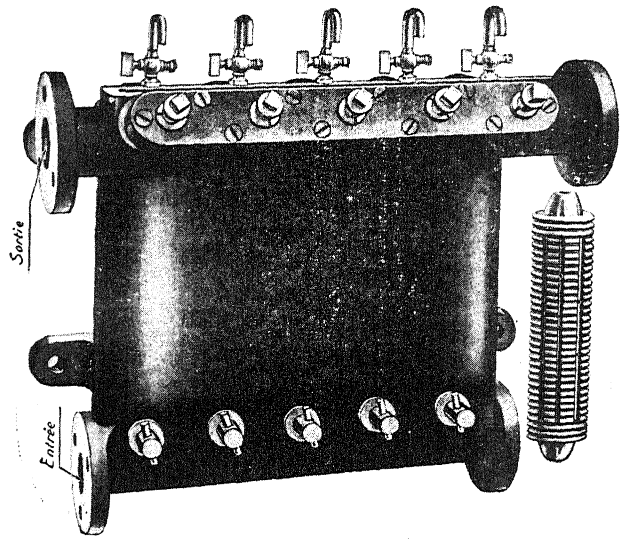
V. **Spinning Spindles.***

Spinning spindles are the most delicate organs of the centrifugal machines. Their great speed—they attain to 10,000 revolutions per minute—raises difficult problems of maintaining the equilibrium. There are various kinds of spindles, namely—

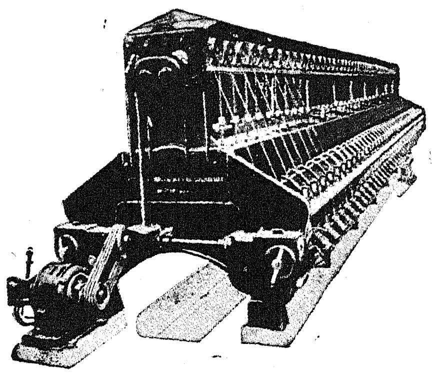
(*i*) Spindles commanded by a belt, similar to those used on twisting machines in the textile industry; but these have now almost completely disappeared.

* In this connection it may be mentioned that the A. M. C. machines have proved very serviceable. They are provided with electric spindles the conception of which is very good and their realization perfect. These machines are built on the latest ideas of very careful and scientific construction, and embody all the latest improvements. The cost of their upkeep is nil, and thus the cost of manufacture is reduced and the production is increased both in quality and quantity.

PLATE V.



Spinning Filter.



Centrifugal Spinning Machine.

(Ateliers Mecaniques de Courbevoie).

To face page 22.

(*ii*) Spindles commanded by gears. In these a helicoidal wheel actuates a worm fixed on the stem of the spindle. A system of cone couplings binds this stem to the upper part, which supports the spinning pot. The different spindles on a machine are connected together by means of Oldham joints.

(*iii*) Electric spindles, which are mostly used now, and which are destined to replace all others in the future.

In principle the electric spindles are actuated by an electric motor, synchronised to the vertical shaft. Their upkeep is small, their speed can be easily regulated, and with their use all noise and vibration are eliminated. At the same time it is easier to work the machines, because each of the spindles is independent, whereas the first two types of spindles require complicated and individual starting up.

Spinning Pots.

The spinning pot, driven at great speed by the spindle, receives the thread, which is still impregnated with the spinning bath liquor. This pot, on the one hand supports the effects of the centrifugal force, and on the other resists the action of the spinning bath liquids. They are made of ebonite or bakelite, or of alluminium treated with ebonite or bakelite.

Godets.

The godets are cylinders of glass or moulded from bakelite matter, with a collar on the side near the machine to prevent drops of acid from falling on the shaft and on the mechanical parts of the drive. Their shaft is fixed either perpendicular to the face of the machine or parallel to the shaft. The outer surface of the godets is smooth or ribbed. The smooth godets give a better drag on the thread by minimising any tendency to slip. With the shafts perpendicular, the projections of acid towards the spinning which take place sometimes with the parallel shafts, are avoided, and moreover, it is easier for the spinner tc pass the thread on to the godet. However, each type has its own advantages.

Funnels and Funnel Supports.

The funnel, which moves up and down, guides the thread to the spinning pot. This funnel is made from a glass tube which opens like a tulip at its upper end. Its height is about 25 centimeters, and compressions

in its diameter at certain points ensure a better guidance of the thread. The lower end of the tube is slightly opened out or slightly turned up.

The funnels are fixed on funnel supports which allow of their being lifted and removed during the doffing operatation.*

Protection of the Spinning Machines.

Owing to the extreme corrosiveness of the spinning bath, special care has to be taken to preserve its mechanical parts. To achieve this, the machines are given a wood casing, covered with sheet lead, and the parts which cannot be protected in this way are painted with anti-acid paint or with a solution having a base of tar.

Ventilation.

Energetic ventilation of the machines is absolutely necessary, otherwise the atmosphere of the spinning rooms will become intolerable and asphixiating. The coagulation of the thread generates sulphurated hydrogen and the rotation of the spinning pots produces the pulverisation of the spinning solution drawn up by the thread.

It has therefore been found necessary to have a sheath in the lower part of the machine, which sucks the spinning solution from the spaces where the spinning pots revolve, and another on the upper part of the machine, which sucks the same from the godets. These sheaths are connected to a general exhaust pipe at the end of the machine. To complete the ventilation, there must be 80 per cent. of humidity with a temperature of about 24 degrees Centigrade.

IV. Finishing Off.

The finishing operations are carried out in different ways, according as to whether the silk has been spun by the parallel or by the centrifugal process. Each of these is dealt with in some detail below.

---

* The ATELIERS MECANIQUES DE COURBEVOIE, have devised a funnel support made entirely of moulded materials, which is impervious to acid attacks, and the handling of which is very simple and easy to regulate, with no fear of its being deranged during the doffings.

Finishing after Parallel Spinning.

The finishing operations in the case of parallel spinning consists of washing and drying on bobbins; of unwinding these bobbins on to smaller ones, with a view to twisting the silk; and finally of reeling the silk into hanks, followed by the desulphurisation of the silk.

The chief operation is the washing, which must be done with great care. All traces of the acid with which they are impregnated, and which might burn the thread during the drying operation, must be removed from the bobbins.

There are many methods of washing. One is to wash by draining, submitting the bobbins to the action of neutralised or slightly alkalised water, which will fall in a shower from a pipe pierced with holes. But this method is rather inconvenient, as it requires much costly labour.

Another method is washing by immersion. A chariot on which bobbins have been placed is plunged for a certain time into a stream of running water. This method is used especially with large bobbins. Its disadvantage is that it uses a great deal of water and keeps the bobbins idle for too long a period.

Another method is washing by pulverisation. By this method the water, arriving in the form of a cloud, penetrates the silk better and consequently the washing is more regular.

There is one more method, and that is washing by vacuum. By this method the water is made to circulate through the bobbins by means of a vacuum created in the interior of the bobbins. This system, which is largely employed for smaller bobbins, has the advantages of consuming only a small quantity of water, and of keeping the bobbins idle for a short time only, as this washing takes only 2 hours, as against 12 hours by the draining and 18 hours by the immersion method.

The material for washing by vacuum is of the simplest type. A rectangular recipient of wood, or of wood lined with ebonite, with a double bottom corresponding to the interior of the bobbins, is laid in a quincunx on indiarubber seams, and its other extremity is closed by a cork of the same material. The insucking pipe is attached to the double bottom.

The water is evacuated from the double bottom into a pit, which has an outlet by which the water escapes. The washing is continued until it is considered complete and regular, after which the bobbins are dried. For this operation the wet bobbins are introduced into the drying tunnels. This is done slowly; the bobbins are brought progressively to the drying temperature, then brought back to the surrounding temperature, or else they are left a moment in the outer air to allow the thread to recover a certain amount of humidity, which is necessary for the reeling process. The reeling is done on special rollers, one above the other, or on twisting reels similar to those employed in the spinning of natural silk. From these rollers the silk can be reeled into hanks.

It has been sought by special machines to reduce the manipulations and to combine the washing, twisting and reeling into hanks on the same machine and at the same time.*

The hanks, after having been laced, are grouped in dozens on tubes of alluminium covered with ebonite or glass, and then the desulphurising and bleaching take place.

Finishing after Centrifugal Spinning

The cakes, when they leave the spinning pot, are taken to the cake chamber, where they are kept for a certain time. It is incorrect to speak of the "ripening of the cakes," for the idea of the cake chamber is to preserve the cakes until the commencement of reeling, and to avoid crystallisation by the formation of soda crystals, which make reeling impossible. The temperature of the cake room is kept at 30 degrees Centigrade and the humidification is provided by steam.

The fragility of the wet acid thread requires that the reeling process should be carried out with the greatest of precautions.

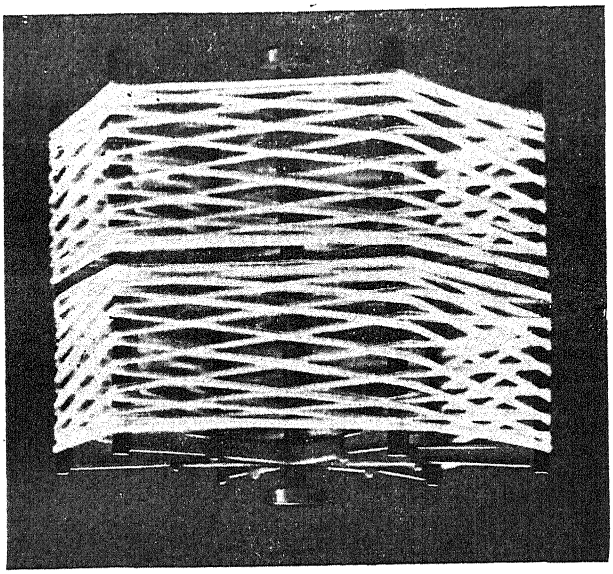
The hanks, when laced, are ready for the operations of washing, desulphurisation and sizing.

Other systems are also in vogue, of which the process consists in giving the cakes a first washing before

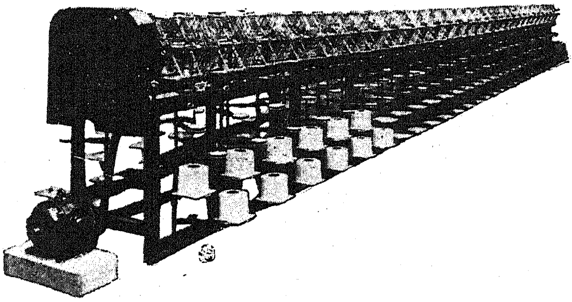
---

* The ATELIERS MECANIQUES DE COURBEVOIE have some of the best types of twisting machines, which are built on these lines, and are largely in use in big factories.

PLATE VI.



Umbrella Swift with Hanks.

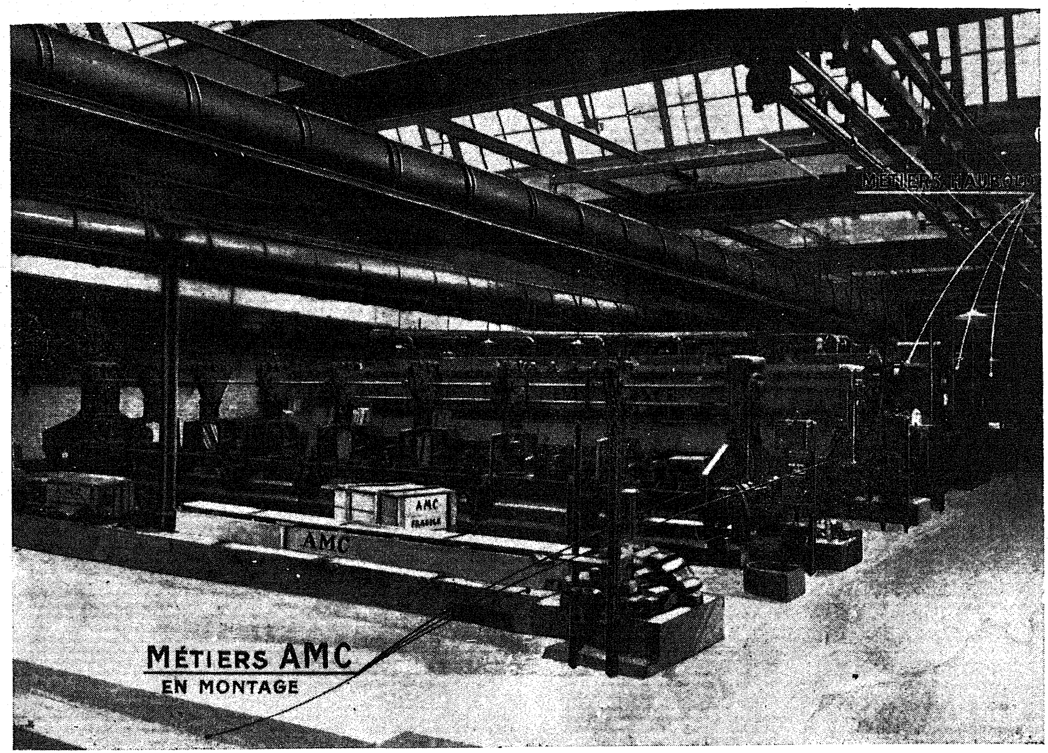


Reeling Machine.

(Ateliers Mecaniques de Courbevoie).

To face page 26.

PLATE VII.



Installation of Spinning Machines.

(*Ateliers Mecaniques de Courbevoie*).

To face page 27.

they are reeled. For this two types of machine are required.

The operation of washing, desulphurising, and sizing the hanks, is done either by hand or by the aid of special machines, which perform the operations automatically. These automatic machines are in use in the most modern factories, for they reduce labour, and they also diminish the manipulation of the hanks, which always results in producing fluffiness which in its turn diminishes the selling value of the silk obtained.

The hanks, after having been washed, desulphurized, bleached and sized, are dried under tension in tunnel dryers. They are then packed for sale.

Summary.

To sum up, it must be carefully noted that in the viscose process it is only by using really good quality materials that one can obtain good results, and that success further depends on the condition that the characteristics of the viscose are watched with the greatest care, extra special care being taken to observe the degrees of ripening of the alkali-cellulose and the viscose; for this the temperatures must be maintained at the determined degree and the atmospheric humidity of the different rooms must be maintained at the desired percentage. To facilitate these controls, the use of registering apparatuses is recommended.

CHAPTER IV.

THE CELLULOSE-ACETATE PROCESS.

THE manufacture of artificial silk from acetate of cellulose is, from the industrial point of view, the most recent process, but in reality the discovery of the product that serves as its base is the oldest of all those that have been mentioned in the foregoing pages, for it dates back as far as 1865, when Schulzenberger and Naudin, by heating some cotton mixed with acetic anhydride at 200 degrees Centigrade in a closed vessel, obtained an acetylised cellulose. In 1869 they published a memorandum on the acetylation of alcoholic composition, in which they declared that they were the first to replace acetic acid by acetic anhydride.

Matters remained there until fifteen years later, when Franchimont treated cellulose with acetic anhydride, with the presence of sulphuric acid employed in small doses to act as a cataletic agent. He observed the formation of ethers of different solubilities varying according to the quantity of acid employed. It can be said, therefore, that it was Franchimont who showed the way to the first practical method by acetylisation.

But so far matters had not progressed beyond the laboratory stage. It was Cross and Bevan who, in 1894, for the first time conducted a research from the industrial point of view by taking out a patent on a tetracetate of cellulose soluble in chloroform, which, according to them, could be used as a substitute for collodion. This was the beginning which ultimately led to the manufacture of acetate silk on a commercial basis. At first the new product was only considered suitable for certain special things, such as uninflammable films,

plastic matters, polishes, etc. But Prince Henckel of Donnersmark without hesitation purchased the inventions of the two English chemists, and under the name of "Cellestron" he put the new product on the market.

But rightly or wrongly, it is held that the first to patent the manufacturing of a thread from this new product were the Americans Monk, Little and Walker, in the year 1902. Sundry other ideas were patented in the United States, Canada, France, Belgium, Hungary, Austria and Germany, but the patents which attracted most attention were those taken out by Bayer & Co., the manufacturers of chemical products. This company treated hydrocellulose with a mixture of anhydride and acetic acid, using sulphuric acid as a catalyst and thus producing for the first time an acetate, the solution of which in alcohol at 70 degrees Centigrade was sold by them under the name of "Sericose" for the purpose of being employed in impression work. But their acetate was not of the desired quality for the manufacture of artificial silk.

Soon other patents were taken out in this connection, notably those of Dr. Henry Dreyfus in Switzerland, who from 1911 to 1913, with the help of his brother, established the natural principles of this industry and produced a silk made from acetate of cellulose, in which acetic anhydride acted on the cellulose to form a matter with more resistance than any other kind of artificial silk, and to which he gave the name of "Celanese".

The considerable period that intervened between the first experiments of 1869 and those of 1913, coupled with the fact that the activities in this direction were interrupted by the Great War, convey a good idea of the difficulties that had to be overcome by those who were carrying on the research work.

It seemed at first sight that in principle the process to be followed was of the simplest, since it was only a question of dissolving the acetate of cellulose in a volatile solvent at a low temperature and of spinning the solution thus obtained under the same conditions as in the case of nitrocellulose. But actually the problem to be solved—one which bristled with difficulties—was for the chemists to produce acetate of cellulose, or more correctly speaking, acetate of hydrate of cellulose, on an industrial basis, in practical conditions of stability and solubility, and that without residue, these being the two conditions which alone would allow it to be spun without trouble. Experiments in this direction have been numerous and varied and the research is not yet ended, as finality has not yet been reached.

At the early stages several different methods of making the acetate of cellulose were used; one was by the reaction of acetic anhydride on the cellulose in a closed vessel at a temperature of 180 degrees Centigrade; another was by getting the anhydride to react in the presence of iodine of zinc chlorate; a third was by impregnating the chlorinated cellulose with an excess of frozen acetic acid, which was subsequently removed by wringing out or pressing, done immediately and rapidly to prevent the chlorine retained by the cellulose from passing into acetic acid; and the fourth method was by a strong reaction of chlorine on cotton at an exceedingly high temperature and for a very long time, thus hydrolising it more or less completely and afterwards acetylising the hydrocellulose thus formed with a variable acetylant solution.

Manufacture of Cellulose Acetate—the Raw Material for Acetate Silk.

It is wellnigh impossible to get an exact idea of the manufacture of acetate of silk, the basic material for

the acetate silk industry, because the information given out by the French and other foreign manufacturers is confusing and not infrequently misleading and contradictory. Still from a close examination of the information given out from time to time, it transpires that the acetates of cellulose can be classified into two principal groups, according as to whether the acetate of cellulose is to be spun dry or wet. In dry spinning, according to the patents taken out by Dreyfus, Eichengrun, Miles and others, the acetate of cellulose obtained is soluble in acetone and insoluble in chloroform. In wet spinning the solution of acetate of cellulose which is obtained can be spun direct, irrespective of whether or not the acetates are soluble in acetone. Most of these acetates are insoluble in acetone but are soluble in chloroform.

The first cellulose acetate prepared was acetate insoluble in acetone and soluble in chloroform. It was Schutzenberger who first succeeded, in 1866, in preparing a cellulose acetate by heating the cellulose and the acetic anhydride in a closed glass tube. Then in 1879 Franchimont, Girard and Skraup prepared cellulose acetate by employing some cataletic agent. These men only worked from a scientific point of view, and it was not until 1894 that Cross and Bevan took out their patent for the preparation, on a commercial basis, of a cellulose acetate insoluble in acetone and soluble in chloroform. But almost at the same time Eichengrun and Becker also succeeded in preparing a cellulose acetate soluble in acetone by hydrolising the tri-acetate with diludep sulphuric acid.

The patents of Guido Donnersmark, Bayer, Dreyfus, Lederer, Mills, and many others, on which the acetate silk industry now relies for its raw material, are only developments of the principle ennunciated by Cross and Bevan, and by Eichengrun and Becker.

Of all the numerous patents concerning the preparation of acetate cellulose, only those have been applied commercially to the manufacture of artificial silk which result in acetates soluble in acetone, that is to say, acetates which can be spun dry, because their solution has a low boiling point (56 degrees Centigrade), and can therefore be easily evaporated.

Although primary acetates have not found favour, from the commercial point of view, yet they have a great importance in the manufacture of cellulose acetate soluble in acetone, or secondary acetate.

Preparation of Primary Cellulose Acetate Solution.

CELLULOSE.—Cotton waste or linters are generally employed in the preparation of cellulose. The method of purification is similar to that for the nitro cellulose.

ACETYLATION.—The cellulose, which should not contain more than 5 or 6 per cent. of water, is heated in a suitable jacketted mixer with a mixture of acetic acid and acetic anhydride, in the presence of a catalyst, e. g., zinc chloride or sulphuric acid. Acetylation is usually carried out at a temperature of 25 to 70 degrees C., the duration of the action varies from 3 to 48 hours, and it depends on the temperature of the reaction, the composition of the acetylating mixture and the catalyst used.

HYDRATION.—After acetylation the cellulose acetate thus obtained is soluble in chloroform but insoluble in acetone. For the purpose of the manufacture of artificial silk or films it is necessary to convert this compound into an acetone-soluble compound, which is done by mixing a further quantity of acetic acid and heating the mixture for some hours at 50 to 70 degrees C.

PRECIPITATION OF THE SOLUTION.—Thereafter the cellulose acetate is precipitated by dilution with water. It is washed well, the water being afterwards extracted by a hydro-extractor, then dried and dissolved in a suitable solvent for spinning, and finally filtered and de-aerated.

Preparation of Acetate of Cellulose that can be Spun Immediately.

Notwithstanding the fact that dry acetate silk spinning is, without doubt, not only more advantageous than wet spinning, but it is also easier, because it eliminates a series of operations in the manufacture, such as washing and drying, and allows of a much higher speed in spinning. Nevertheless there has lately been a tendency to return to the wet spinning process. Wet spinning certainly has its advantages also, as it allows of the use of the solution of cellulose acetate immediately after acetylisation for direct spinning, without having to separate the acetate and redissolve it in acetone. It also eliminates the question of the recuperation of acetone and simplifies the recuperation of the solvent of the acetate employed.

It is true that wet spinning of cellulose acetate has not so far been employed commercially to any great extent, yet it seems that the question of wet acetate spinning has been successfully solved and that some factories wish to apply it industrially. As already stated, there are a series of patents dealing with the preparation of solutions of cellulose acetate that can be spun direct, the latest success in the solution of this problem having been attained by the Zdanowich patents; but as a detailed examination of these patents is outside the scope of this work, it will be sufficient to say that the primary cellulose acetate thus obtained is sent out of the factory ready for spinning, and that it has a remarkable stability.

Preparation of Secondary Acetate of Cellulose Soluble in Acetone.

Secondary cellulose acetate, soluble in acetone, is the acetate used as the raw material in nearly all factories making acetate silk. To prepare it, as already stated, it is necessary to start with primary cellulose acetate. To obtain secondary cellulose acetate, also called hydrated cellulose acetate, two methods are possible. One is to start with a primary acetate already isolated by hydrolising it; and the second is to hydrolise it immediately before isolation in the acetic solution of primary acetate.

It is difficult always to obtain the same acetate. In order that the acetate prepared may always be of the same quality and uniformity, rigid adherence to the conditions prescribed for the acetylisation is advocated, in order that, particularly at the commencement, the

action through the acetylising mixture may be uniform and simultaneous on the whole mass of cotton. Small differences of temperature in the mixing, or difference of humidity in the surrounding atmosphere and other unforeseen changes, often result in acetates that are very heterogeneous. As a general rule 70 kilograms of cotton is sufficient to produce 100 kilograms of acetate. (One kilogram = 2.3 lbs.)

Spinning of Acetate Solution.

Two methods of spinning acetate solution are in vogue, namely, wet spinning and dry spinning. The latter is the only method that has been successful from the commercial point of view.

In the dry spinning method the acetone solution, containing 5 to 20 per cent. cellulose acetate, is projected into a closed compartment and the solvent is evaporated by means of hot air, resulting in a solidified thread which rolls itself on to a bobbin in the lower part of the compartment.

The whole difficulty lies in establishing these heating compartments, and in maintaing the conditions of temperature, as also the recuperation of the acetone gases, which in itself is a costly process, because it is on the successful recuperation that the cost price of the silk depends.

In wet spinning a solution of the cellulose acetate in acetone or other solvent can be spun into baths of hydrocarbons, coils, or aqueous solutions of salt. It has been suggested that the acetylating mixture itself can be suitably diluted and spun direct. In wet spinning the thread is collected on bobbins and then washed.

In both cases the thread, wound on the bobbins, is twisted on machines similar to those employed in twisting natural silk.

One of the advantages of the acetate process is that after the preparation of the solution of acetate, less machinery is needed than in other processes, and one can foresee the time when the manufacturer will be able to purchase his acetate from chemical factories ready made, and to spin the thread with the aid of some heating boxes. But that time is still far distant, for the

problem is a complex one and the secrets of manufacture are jealously guarded by the patentees.

As matters stand at present, the acetate process is not greatly in favour with manufacturers, as is evident from the fact that out of the total world production of artificial silk only 10 per cent. is manufactured by this process. The reasons for this are the higher cost of the raw materials, the difficulty in recuperating the solvents, the considerable waste in the process of manufacture and the dyeing difficulties. Moreover, the process of manufacture is more complex than the viscose process.

CHAPTER V.

THE CUPRAMMONIUM PROCESS.

THE cuprammonium process, obtained from the properties of the Schweitzerfun liquid, was discovered in about 1890 by Deispessis. The collulose solution was compressed and driven through very small holes into a bath of hydrochloric acid, where the viscous jets congealed.

The process was modified by Pauly, who used acetic acid for the coagulation instead of hydrochloric acid. After this Fremery, Urban and Bronnert made some valuable contributions towards improving the method of preparation of the cellulose with a view to its dissolution in copper-ammonium liquid.

The first company to work this process was established in 1900 under the title of Compagnie Française de la Soie Parisienne. Very soon after a branch of the same factory was started under the name of la Soie Artificielle d'Izieux.

At Lyons a company named A. Lumièrs et Fils and another named Societe Anonyme pour I'Exploitation des Textiles Lyonnaises, came to a mutual arrangement for exploiting the process.

Then Germany took the lead, and very soon the Vereinige Glanzstoff Fabriken became the premier copper-silk manufacturing firm of the world.

In Belgium many companies were formed, namely, les Soieries Nouvelles de Bruxelles, la Societe Generale pour la Fabrication et l'Exploitation de la Soie Artificielle, la Soie Artificielle Obourg, and la Societe pour la Fabrication de la Soie Vegetale.

The manufacture of cuprammonium silk comprises the following operations :—

(1) Preparation of the raw material.
(2) Dissolution of the cellulose.
(3) Spinning of the solution.
(4) Finishing off.

(1) PREPARATION OF THE RAW MATERIAL.

The cellulose used for the cuprammonium solution is generally cotton waste or linters, which after being suitably purified by a process almost similar to that adopted for viscose silk, is bleached in gavel and rinsed in acidulated water; then it is thoroughly washed and allowed to drain off.

(2) DISSOLUTION OF THE CELLULOSE.

The solution of copper-ammonium is prepared by blowing air at a low temperature into a double jacketed towee containing ammonia and pure copper shavings or electrolysed copper. The solution of ammonia oxidr is mixed with a solution of copper sulphate, and to this is added liquid washing soda. The solution thus obtained is introduced, together with the cotton, into a reservoir specially made for its dissolution. The dissolution is completed after 7 hours of mixing. The viscosity of the liquid is verified. It is then passed through graduated filters that become finer and finer, and finally it is brought under pressure into the reservoirs.

(3) SPINNING OF THE SOLUTION.

For a long time sulphuric acid was used for coagulating the thread thus obtained but this acid is now being replaced more and more by caustic soda, in view of the numerous inconveniences attending the use of sulphuric acid, for instance, the special lead reservoirs that are necessary, the obligatory painting of the machines with lime, and the necessity for the workmen to use indiarubber gloves, in order to guard against its corrosive action.

The cellulose solution is brought under pressure to distributors, which are plunged in the baths containing the coagulating liquid. The solution comes out

through the holes in the Jena glass jets. A guide thread gathers together the threads formed and winds them on glass bobbins, the thread being spread along the rollers by a device for carrying it backwards and forwards. The bobbins are arranged so as to dip partly into a bath of acid. When filled the bobbins are washed in a bath of acetic or formic acid and subsequently treated in a bath of white soap, and then dried.

(4) Finishing off.

The glass bobbins are reeled on to smaller wooden bobbins. Then the thread is twisted and reeled into hanks, which are sorted. The copper still remaining is eliminated by being washed off in a bath of diluted acid.

Although the proportion of the world's output of artificial silk by the the cuprammonium process is very small to-day as compared with that by the viscose process(see page 15), yet for some purposes cuprammonium silk is considered superior to the other artificial silks, mainly on account of its subdued lustre, softness and greater strength. The economical working of the cuprammonium process depends largely on the successful recovery of the copper compound, and to a less extent of the ammonia.

CHAPTER VI.

THE NITROCELLULOSE OR COLLODION PROCESS.

IN 1884 the inventor, Chardonnet, took out his first patent, declaring that he had obtained his silk from a liquid which was nothing more nor less than the collodion used in chemistry and photography. He closely observed the silk worm at work and imitated its methods by compressing the collodion and pressing it through jets plunged in water, and having gathered together the several threads thus obtained, he drew them out of the water in a bunch, dried them and twisted them.

The first company was founded at Besanscon. Its success was short-lived, for the silk was not denitrated and consequently it was very inflammable, and therefore the consumers quickly abandoned this dangerous material. Chardonnet made further research with a view to getting over this disadvantage, and after many experiments he fixed upon the action on the material of hydrosulphides of calcium as being the best means of rendering it less inflammable.

This company was then reorganised, and after a long and difficult period of experiments, artificial collodion silk was produced, and it took its place amongst the textile materials on the market; and from that time onward its progress on the road to perfection became more marked. Thereafter companies were also formed in other countries, and they adopted the Donnet patents. These are:—

La Société Belge de Tubize.

La Société Allemande de la Soie Chardonnet.

La Société Hongroise à Sevar.

La Société Italienne.

La Société Americaine, known at first as

La Société Lyonnaise de Soie.

During the year 1904 the Chardonnet patents became public property and more new companies were formed, namely, la Société Allemande Kunstseide Gessellschaft, formed at Julich near Cologne by the Nobel Dynamite Trust Co. of London, and la Société Anonyme Belge pour la Fabrication de la Soie Artificielle of Brussels.

The manufacture of collodion silk consists of the following operations :—

(1) Preparation of the raw material.

(2) Nitration of the cotton.

(3) Dissolution of the cotton powder.

(4) Filtration and spinning of the collodion.

(5) Denitration.

(6) Finishing off.

(1) Preparation of the raw material.

In the beginning raw cotton from America was used. To-day linters are found good enough. (Linters are the downy part around certain cotton seeds). To remove all impurities, the collodion has to be filtered carefully before it passes through the jets. The grease is removed from the linters by steeping them in a bath of boiling soda solution, and is beaten with wooden battens. This fibre is then put into a bath of hydrochloric acid, and subsequently it is rinsed out and dried at about 80 degrees C.

(2) Nitration of the cotton.

The operation of nitration consists of treating the cotton for about one hour with a mixture of sulphuric acid and acetic acid in proportions which vary according to the quality of the raw material, temperature, etc.

The progress of the operation is verified under polarised light, and the viscosity is kept under control by close observation under a microscope. The change of colour the fibre undergoes is the index which decides the end of the operation.

This operation takes place in nitration turbines which turn slowly—turbines of the type used in the manufacture of explosives. Precautions must be taken to protect the workmen from the nitrous gases given off, which have a caustic effect and can affect the mucous membranes.

(3) DISSOLUTION OF THE COTTON POWDER.

The cotton powder thus obtained is washed and rinsed and dissolved in a mixture of ether and alcohol, and their proportions depend upon the required strength of the cellulose nitrate solution and upon the method by which the solution is to be spun. It takes about 5 to 8 hours to effect the dissolution.

4) COLLODION SPINNING.

There are two methods of spinning collodion (nitrocellulose solution), and these are similar to those of spinning the cellulose acetate solution already described in in the preceding chapter, that is to say, wet spinning and dry spinning.

Wet Spinning —The wet spinning method is similar to that described for viscose and cuprammonium spinning, except that water is generally employed as the coagulating bath. The advantage of this method is that the solvent can be recovered economically by a simple process. This method is, however, slow and has not been so extensively employed as the dry spinning method.

*Dry Spinning**.—In the dry spinning method no coagulating bath is used and the solvents are evaporated by warm air. As the solution is forced through the jets it solidifies forthwith, and the threads thus formed

* A most up-to-date plant for dry spinning is manufactured by the well-known French firm of Ateliers Mecaniques de Courbevoie. This plant is most scientifically constructed, and is economical. The spinning machine gives a constant and regular pull to the thread and the thread obtained is uniform and without ridges. The distance between the jets and the bobbins is so arranged that there is greater spinning speed and a higher output per spinning machine than in the case of other machines.

are collected straight on to a bobbin or in a centrifugal spinning box. This method of spinning has a distinct advantage over the wet method, inasmuch as the output per jet is considerably greater, and the amount of solvent required is comparatively small as compared with that required for wet spinning. But the recovery of the solvent, on which the success of the whole process depends, requires a more complicated plant.

(5) DENITRATION.

Denitration has to be carried out very carefully under controlled conditions as to temperature and duration of the process, because without it the silk obtained retains the properties of guncotton and is therefore very combustible. In this process the reeled skeins are subjected to a bath of hydrosulphides of calcium containing a small quantity of ammonia. The operation lasts one to two hours. The thread, which before denitration had a glazed appearance, assumes a suppleness and brilliancy similar to that of real silk, but its tenacity is diminished a little. After denitration the silk is rinsed in pure water and soured by hot diluted hydrochloric acid, so as to remove any iron sulphide remainig on it.

(6) FINISHING OFF.

The finishing operations consist of bleaching in the usual way, followed by sizing. The threads are then wrung in centrifugal turbines and dried in tunnel dryers. They must not be thoroughly dried, for the silk must retain a small percentage of humidity to keep it supple.

Conclusion.

Nowadays the world's production of artificial silk by the nitrocellulose process is on the wane and is likely to diminish further, because the process is more complicated and more expensive than the viscose process. The economic success of the former process depends upon the recovery of acids employed in nitration, and of the solvents used in the dissolution of the nitrocellulose. Moreover, the thread so produced has now little advantage over the other artificial silks as regards strength and appearance.

CHAPTER VII.

MISCELLANEOUS PROCESSES.

THE four processes described briefly in the preceding chapters are those that have become established on a commercial manufacturing basis and have survived the test of time. There are, however, several other processes which are of interest from the point of view of the chemist. These have failed to realise expectations from the industrial point of view. The most important of them are:—

(1) Gelatine or Vandura Silk.
(2) The Zinc Chloride Process.
(3) The Cellulose-ether Process.
(4) Cellulose and Sulphocyanide Solution.
(5) Solutions of Casein.

These processes fall under two categories. By the first the artificial threads are produced from aqueous solutions of gelatine or from solutions of cellulose and zinc chloride. In the second category threads are produced from cellulose ether, solution of cellulose and sulphocyanide salts or solutions of casein.

(1) Gelatine or vandura silk.

In 1894 Millar patented the production of artificial silk thread from gelatine solution. A company was started to work this process, but it only had a short existence, as the artificial silk produced was not strong enough for textile requirements.

(2) The Zinc chloride process.

The spinning of cellulose dissolved in zinc chloride solution has been used to some extent in the production of threads for electric lamp filaments, but it has not been a success, as the threads produced were weak on

account of the strong hydrolytic action of the zinc choride on the cellulose.

(3) THE CELLULOSE-ETHER PROCESS.

The cellulose-ether process has aroused considerable interest, as the cellulose-ethers have a very wide range of solubility. The solution of the ether in organic solvents can be spun by the wet or dry spinning method. The process is in course of development, and it is likely that it may be further developed in the future, provided that it can compete successfully with the other processes already established. It is expected thatthe final thread will be similar to that produced by the acetate process.

(4) CELLULOSE AND SULPHOCYANIDE SOLUTION.

Attention was recently drawn to the possibility of making cellulose solution by the action of salts of sulphocyanic acid on cellulose, which would be suitable for producing·films and filaments. So far as can be judged at present, however, it does not seem very likely that it will ever be of much value for artificial silk production.

(5) SOLUTIONS OF CASEIN.

The production of thread from alkaline solution of casein by spinning into an acid-alcohol solution has been attempted; but the artificial silks produced therefrom were deficient in softness and strength. Consequently it was not a success commercially.

General Remarks.

Various suggestions have been put forward for the production of artificial silk from other solutions of cellulose or compounds, but as the successful exploitation of a process is governed by the factor of working cost, these processes have not attained to any degree of recognition from the commercial point of view.

It has already been mentioned that almost 90 per cent. of the world's total output of artificial silk is being made by the viscose process. The displacement of the old cuprammonium and nitrocellulose processes by the viscose process has been very rapid during the last 18

years. The majority of new enterprises all the world over are working this process. This fact is largely due to the low price of the raw materials and chemicals employed in this process. The price of the wood pulp, caustic soda and carbon bisulphide—the main ingredients in the viscose process countries, where cotton is not plentiful—are far cheaper than the raw materials used in the acetate and other processes. Generally speaking, the survival of any process over the viscose process will largely depend upon the cost of the raw materials used and the quality of the produce turned out.

Artificial silk has now taken a definite place in the textile industry. The price of viscose silk has now reached its pre-war level but its quality has greatly improved since the war. The following table shows the fluctuations in the price of artificial silk, in comparision with those of other fibres.

Fibre.	1913	1919	1920 (Feb.)	1920 (Oct.)	1926	1927	1929
	Price per lb in England.						
	s. d.	s. d.	s. d.	s. d.	s.d.	s. d.	s. d.
Artificial Silk (viscose), 150 denier	5-3	16-0	19-3	12-6	6-0	5-0	5-0
Canton Silk, (discharged) (common sizes).	17-4	59-8	104-0	46-8	31-4	23-0	11-6
Italian Silk, (discharged) (common sizes).	21-4	73-8	126-11	59-4	40-8	36-0	15-0
Egyptian mercerised cotton (=151 denier)	2-1	7-10	17-5	7-4	4-2	3-5½	2-6
Botany worsted (=159 denier).	3-6	17-6	20-0	12-0	6-9	6-7	3-9

Courtauld, one of the largest manufacturers of artificial silk in England, has stated that artificial silk is to-day, on its merits, by far the cheapest—the best value—of any known fibre.

The raw materials and chemicals used in the viscose process are all available in India in large quantities and at a low cost, as compared with other countries, and therefore the cost of production here will also be correspondingly lower. Moreover, the raw materials required for the other processes are scarce and costly in India, and this fact still further throws the balance in favour of the viscose process. It will therefore be possible for India to compete very successfully with other manufacturing countries in the production of viscose silk.

In view of this and the facts set forth in the foregoing chapters, the conclusion that the viscose process will be most suitable and profitable for India would appear to be irresistable.

CHAPTER VIII.

MISCELLANEOUS PRODUCTS DERIVED FROM VISCOSE.

SO far the manufacture of the artificial fibre known as artificial silk has been described. But there are certain special varieties of artificial fibre which are of some importance and are produced by methods analogous to those employed in the production of textile artificial silk. The use of these artificial fibres has to a certain extent, depended on the vagaries of fashion and the ingenuity of manufacturers in finding markets for them. The most important of these fibres are known as staple fibre, artificial wool, artificial straw, caps for bottles and transparent paper.

The very same machinery as is used in the manufacture of the viscose rayon yarn is also used in the production of these artificial fibres up to the spinning stage, when different machines are required.

Staple Fibre.—In the manufacture of artificial silk there invariably is a certain amount of waste. This waste during the past years had only a limited scope and industrial use. It was combed and spun or was worked up into other fibres. Before the war, however, suggestions were put forward to produce large quantities of short-length waste fibrous materials from viscose, but they did not go far in manufacturing developments. During the war when the textile materials in Germany had run short, the production of such a fibre received considerable attention and large quantities of the so-called staple fibre were produced from viscose. These fibres were worked in, to a great extent, with wool and cotton. After the war, when the supply of natural

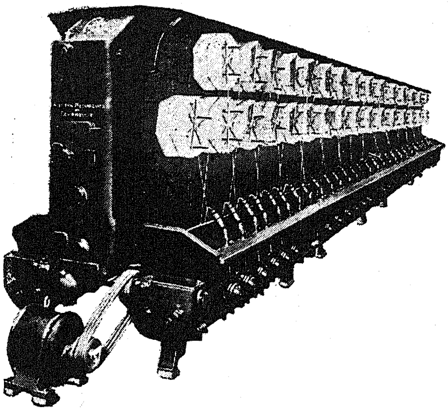
textile fibres became normal, the use of staple fibre diminished, as the production of artificial silk was then found more profitable. In the last few years, however, the cost of production has been lowered by the introduction of improved methods of manufacture, and by the fact that textile manufacturers have become better acquainted with the use of artificial silk. However the cost of production of staple fibre is still lower than that of the artificial silk filament, and it is therefore important from the industrial point of view, inasmuch as it is put to numerous uses, as a standard admixing material with natural fibres.

Staple fibre is available in the market in tufts of filament of lengths varying from 3 to 15 centimeters. It is obtainable in many qualities, and with full lustre, lustreless, or with subdued lustre, and with curled or rough surface.

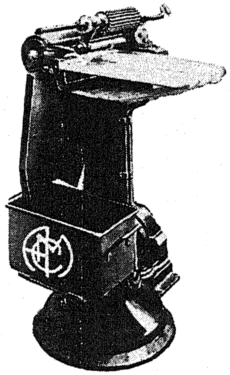
Staple fibre is manufactured from viscose solution on account of its lower cost of production. It is generally mixed with either wool or cotton and is spun into a mixed thread. It can also be spun satisfactorily alone. A mixture of staple fibre with wool, cotton, worsted, and even real silk, is said to contain 30 to 75 per cent. of staple fibre. The mixture of staple fibre with wool has found more favour, as the properties of the one are opposed to those of the other. Wool is soft to the touch and warm, and the staple fibre, when mixed with it enhances its appearance and produces special dyeing effects, and therefore the product is much liked. The use of staple fibre combined with cotton has not so far been so extensive as that with wool.

There is good scope for the use of staple fibre. As the methods of spinning are developed it is becoming more and more a standard product for admixing with natural fibres.

PLATE VIII.



Machine for the Manufacture of
Artificial Silk Staple Fibre.



Machine for Cutting
Staple Fibre.

(Ateliers Mecaniques de Courberoie).

Method of Production.—There are various machines on the market for producing staple fibre. A large number of filaments can be spun by using a jet with a great number of holes, and collecting the composite thread on a suitable reel. Sometimes a number of spinning points are put together and the thread from them is collected on one reel. The jets usually have 500 holes each with a denier of about 1.5 per filament. In spinning such a large number of threads, special attention has to be paid to both circulation and efficient ventilation, owing to the large volume of gas produced.

The untwisted skein thus produced is washed, desulphurised, bleached, soured and dried, and then it is cut up into the required staple lengths.

In recent years the German firm of Dusseldorf-Ratinger Machinen A. G. E., Wurtz, has patented an ingenious machine for the production of staple fibre by the dry spinning method.

In still more recent years an improved type of machine has been placed on the market by the notable French firm of Messrs. Ataliers Mecaniques de Courbevoie.

Artificial Wool.—Some varieties of the staple fibre, which have little or no lustre, with a roughened surface and curly appearance, have been erroneously called "Artificial Wool". It is so termed because this material compares favourably in finish and appearance with natural wool. But it compares unfavourably with wool in the matter of retaining warmth. This material has found some favour with the textile manufacturers on account of its enhanced spinning value. It seems doubtful, however, whether such material is likely to be extensively used, unless it is proved to have any special merit, or becomes considerably cheaper than natural wool.

Artificial Straw.—Artificial straw is manufactured

by forcing the cellulose solution through a jet specially constructed, and a flat ribbon-like material is thus produced. It has, when finished, a bright, semitranspa-rent ribbon-like appearance, and is known as artificial straw. This material has so far had only a limited use. It is used for making straw hats, and can also be used as a substitute for straw in the manufacture of other articles; but the demand for it will depend on the vagaries of fashion. In India especially there is not much chance of its success commercially.

Caps for Bottles.—Viscose caps have found great favour with many manufacturers. They are used to close bottles of scent and chemicals, jars, bottles of wine, etc. These caps can be manufactured in many different varieties so as to imitate silk, metals—either gold or sil-ver—and marble, and they can be either dull or brilliant.

Before the introduction in the market of viscose caps, the caps were manufactured from various other materials, such as wax, tin, parchment and gelatine. But all these caps are found to have some serious draw-back or other.

Wax caps, though airtight, are fragile and cannot withstand even a small shock, and they are useless for such liquids as cannot bear warmth.

Tin caps, though easier to use than wax caps, are not airtight and cannot be used where hermetical sealing is required.

Parchment caps, like tin caps, are useless for hermetical sealing, and at the same time they are costly, and for putting them on, skilled and experienced work-men are required.

Gelatine caps have not found much favour because they can resist neither humidity nor heat.

Viscose caps are easy to use. Any workman, or even a boy, can be set to do the work of puttiug them on to the bottles. They are watertight and cost less to make than any of the other caps mentioned above. In view of these advantages, there seems to be good scope for the manufacture of viscose caps, which are likely to develop in future along with the chemical industries in India.

Viscose caps are manufactured by a special automatic machine, from the viscose solution direct. The A. M. C. automatic machines for the purpose produce three thousand caps per hour, and the amount of labour required is very small; all the work to be done by the workmen consists in feeding rollers to the machine, and in receiving them at the other end with the manufactured congealed caps.

These automatic machines are fitted with wooden rollers with glass tubes at each end. The diameters of the glass tubes correspond to the sizes of the caps to be made. By means of special chains the rollers are set in motion one after another in such a manner that the glass tubes plunge into the viscose bath, where they receive a uniform covering, and thereafter dip into the coagulating bath. This operation lasts about 20 minutes. Finally the rollers run on to a table where they shake off the caps. The rollers are then ready for refeeding into the machine. The caps are collected and taken to another machine which cuts them, and then they are desulphurised and bleached.

Transparent Paper.—(This subject is extensively dealt with in the next chapter).

CHAPTER IX.

TRANSPARENT PAPER.

TRANSPARENT paper, technically called cellophane, properly comes under the category of plastics, and not under that of artificial fibres.

Transparent paper has been put to numerous uses. Generally it is used as a wrapping material for many commodities, such as soaps, bottles of perfumes, etc., cigars, cigarettes, collars, shirts, ties, caps, confectionery, etc. It is made in various qualities in thin and thick sheets, in small bags, tubes and envelopes; also in various colours and with the appearance of linen, alpaca, silk, *crepe de chine* and moire. On it trade marks, advertisements, etc., etc., can very easily be printed.

It is sold in the market in sheets about 37 inches by 37 inches, weighing about 37 grammes. The sale price is 60 francs (about Rs. 9) per kilogramme (1kg. equals 2.3 lbs).

Cellophane has become popular because of its high transparency, and because it imparts an agreeable appearance to the articles wrapped in it, while at the same time it protects them from dust and humidity, which, in variable climates such as that of India and most other countries, is a distinct advantage. It also saves the hands coming into contact with articles, which, at the same time remain fully visible. Thus it is entirely hygienic, which is particularly advantageous in the case of medicines and articles of food.

This paper is also used for the decoration of shop windows, as on it many designs of flowers, etc., in various colours, can be printed. Thus employed, it

gives the appearance of stained glass.

Some manufacturers are now specialising in making cinometograph films from cellophane, which advantageously replace the celluloid pellicules, the former being non-inflammable.

In addition to those already mentioned, there are also other things that are made of transparent paper. Some of these are beautifully coloured carpets, curtains that do not get dusty, trimmings for armchairs, divans, and also bags, hats, shoes and waterproofs for ladies. All these articles are non-inflammable.

Process of Manufacture.—Transparent paper is made from viscose. The process of manufacture of the viscose is the same as in the case of viscose silk, which has already been described in the chapter on the subject. At the spinning stage, instead of being spun into thread for weaving, it is consigned to a special automatic machine about 60 yards long, which works continuously without stopping, except for cleaning about once a week, and which automatically carries through all the operations necessary in the manufacture of the transparent paper.

This process of manufacture was first discovered in 1907-08 by a Frenchman named Brandenberger at Bezons (France), and the automatic machine is constructed according to the patent taken out by him. The entire machine consists of four different sections, namely, (1) the hopper or distributor, the function of which is to distribute the viscose evenly over the surface of the first coagulating roll; (2) the coagulating, neutralising, desulphurising, bleaching and dyeing bath—the last named, if and when necessary; (3) the drying apparatus; (4) the mechanism that dries all the parts of the machine at different speeds according to requirements, in order to

obtain the finished material.

The production of this machine amounts to one thousand kilogrammes of transparent paper in 24 hours. The speed of the machine decreases when the thickness of the paper increases. That is to say, one film weighing 27 grammes and another weighing, say, 60 grammes, cannot be rolled at the same speed: in the latter case it will be slower.

Dyeing and Printing.—The dyeing of the transparent paper film can also be done separately at a speed of 40 to 50 meters per minute. To produce the different patterns of films, the film is made to pass between two rollers, one of which is heated to 60 or 70 degrees Centigrade, and is engraved according to the desired pattern. In case of extraordinarily delicate patterns being required, heavy rubber rollers are used, which are propelled by the other rollers, the film taking the impression of the designs on the lower rollers. Afterwards the film is dried and then rolled on to a smooth roller. It is then ready for marketing.

Owing to the great depression in the rayon yarn industry in Europe during the last few years, a good many artificial silk manufacturers have started to manufacture viscose transparent paper. As the machinery for the manufacture of viscose silk and transparent paper is common to both up to the point of spinning, all they had to do was to add to their plant the automatic machine for producing the latter. In England Messrs. Courtauld and Clayton have started the transparent paper industry very recently, and several French and German firms have also taken to this industry, because the margin of profit is almost double that of artificial silk, and the transparent paper is becoming increasingly popular.

In a country like India, where the viscose industries have not been introduced at all as yet, the artificial silk industry stands the best chance of really flourishing; but with the additional expenditure of, say, about Rs. one lakh, the transparent paper manufactory can also be started side by side with it. At the present moment there is not a particularly large demand for the transparent paper, but the chances are that it will become very popular in the near future, when it becomes better known, and the margin of profit being great, the additional expense will be well worth while, especially if at any time dumping of artificial silk by countries like Japan is resorted to.

CHAPTER X.

A PRACTICAL SCHEME FOR THE INTRODUCTION OF THE ARTIFICIAL SILK AND TRANSPARENT PAPER INDUSTRY IN INDIA.

INDIA is importing a large quantity of artificial silk from the various manufacturing countries. A close survey of the statistical reports on the subject shows clearly that there is an ever increasing demand for it in this country. Large quantities of artificial silk yarn are imported each year by Indian textile manufacturers. One or two textile mills have recently started to manufacture artificial silk textiles from imported yarn and they are competing against Japan with a considerable measure of success. During the last few years, on an average about eight million pounds of rayon yarn, at an average cost of Re. 1-4-0 per pound have been imported annually. Besides this nearly sixteen million yards of artificial silk cloth is imported into India annually. This enormous consumption of artificial silk in one form or another on the one hand, and the fact that there is not a single artificial silk factory in India, on the other hand, leads one to the irresistable conclusion that while there is a great demand in India, that demand is being met by foreign countries, especially Japan and Italy, whereas it should be met by India herself, and that to the great benefit of India.

The statistics published by the International Bureau at Geneva show that the wants of humanity in textile fabrics have increased from 60 million lbs in 1921, to 189 million lbs in 1925 and to 431 million lbs in 1929. The demand for wool has increased by 1.34 per cent., for natural silk by 6.52 per cent., for cotton by 6.91 per cent. and for artificial silk by 22.05 per cent. This shows that

the increase in the demand for artificial silk has outweighed that for all the other textiles put together. It can safely be said, therefore, that the demand for artificial silk will continue to increase, and that there is a brilliant future for this industry throughout the world, and especially in India. In spite of the fact that the use of artificial silk yarn by Indian textile mills has been banned by the Indian National Congress, there has been an increase in its imports. It goes without saying, therefore, that in the event of this industry being introduced into India, there will be a still further large increase in its demand in this country.

The next question that arises is whether the climatic conditions in India are detrimental to the manufacture of artificial silk.

Some time back an enquiry into this question was made by a European firm of repute, and for some reasons best known to themselves they gave out that the climatic conditions in India are not such as would permit of the manufacture of artificial silk. However, a reference to the list of countries in which it is actually being manufactured (*vide* pages 8 and 9 *supra*) will show that climate plays a very unimportant part in the matter, as in no country in the world where this industry is extant do there exist those ideal conditions of a uniform temperature and humidity, considered to be so essential for the manufacturing process (29 degrees C. and 80 per cent., respectively), throughout the year. In parts of Germany, Russia, North America and Japan the summers are very hot and the winters very cold; in Brazil, Italy and Spain the average temperature is relatively hot; Canada is comparatively cold, the winters there being particularly long and severe; and yet in all these countries the industry has flourished. All that is really required to ensure its success is an abundant supply of water and

plenty of raw materials. The necessary uniformity of temperature and humidity can easily be, and is being, brought about by artificial means, by setting up special plants for the purpose, the building being constructed with double windows, isothermic walls, etc. Therefore the correct answer to the above question is in the negative.

Another question is whether other conditions in India are favourable to the industry.

There is a large and increasing demand for artificial silk in India, as has already been demonstrated. This being so, the further points for consideration are as to the availability of raw materials, labour and machinery, and capital.

Capital.—As to capital, there should be no difficulty, since money in India is lying idle and the rate of interest in banks has fallen very low. Consequently people in India are out to invest their money in sound business propositions instead of banking it, which is evident from the fact, *inter alia*, that during the year 1932 a large number (not less than a hundred) of sugar manufacturing companies have been floated, each with a capital of Rs. 15 to 20 lakhs on an average. If it is shown that the artificial silk industry would be as profitable as sugar, even without the protective tariff which the latter enjoys, there is no reason why capital for the former also should not be forthcoming. The question of profits will be dealt with later on in this chapter.

Labour and Machinery.—It is a well known fact that labour in India is very cheap and abundant, far cheaper, in fact, than in the United States of America, England, Germany, Italy, and even Japan, the two last named being the principal countries which are supplying India's demand for artificial silk. The establishment of a factory on a commercial and economical basis, with a

minimum turnover to begin with, requires 300 ordinary and 50 skilled labourers. Since the advent of hydro-electric instalations in many provinces in India, electric motive power is cheap. The machinery for artificial silk, in common with that for other industries, has to be imported. For the services of experts in the initial stages of the industry, satisfactory arrangements can be made with the manufacturers of the machinery. As for skilled labour, there are already available in India a great number of labourers skilled in the art of spinning and weaving, and they can be had at comparatively cheap rates.

Raw Materials—The basic raw materials required for the manufacture of artificial silk are wood pulp, or cotton waste, or waste paper, and the chemicals required in the course of manufacture by the viscose process are caustic soda, carbon disulphide, disulphuric acid, amonium sulphate, zinc sulphate, soda sulphite, bleaching liquid and white soap. Practically all over the world artificial silk is manufactured from wood pulp imported from those countries which possess huge forests. In Europe it is imported from Sweden and Norway, where the pulp is made from fir trees (spruce), and pressed into sheets, in which form it reaches the manufacturers of rayon textiles. In the United States of America they obtain it from Canada.

Artificial silk made from cotton is of far superior quality to that made from wood pulp. In India very large quantities of short staple cotton are available and at very low rates, as this kind is not favoured for textile purposes. Moreover, the percentage of yield of artificial silk from cotton is far greater than that from wood pulp; wood pulp yields 30 per cent. and cotton 85 per cent. Besides this, there are many chemical works in India where almost all the necessary chemicals are manufactured, and are available at favourable rates.

The only other thing of importance necessary is an abundant supply of water, about which there can be no difficulty in India with its many large rivers and canals.

Then there is the question as to the kind of locality in which this industry should be located, and on what scale it should be established. Bearing in wind the primary needs of the industry, the factory should be located at a place that is—

(1) near a railway line, in order to provide easy transporting facilities for the raw materials and finished products;

(2) near a commercial and industrial centre;

(3) near a river or canal, where water is available in sufficient quantities. The water should be as pure as possible; it should at least be free from chlorides, therefore the seaside will not be a suitable locality. The quantity of water required for each pound of the finished product is about 225 gallons.

A factory with a daily production of at least 1300 pounds of artificial silk can be worked on sound economic principles.

Estimate.—The total cost of the ground, buildings and a complete plant and outfit, including a laboratory plant and the services of the experts for 18 months, during which period they would train Indian young men to carry on afterwards, with a guaranteed production of 1300 lbs. daily is estimated at .... Rs. 13,00,000

Working capital	,,	5,00,000
	Total Rs.	18,00,000

The actual cost of the finished product, including a sinking reserve and overhead charges, comes to As. 11-6 per pound. Taking the average wholesale price of im-

ported artificial silk in India, as given in *The Indian Trade Review*, as Re. 1-4-6 per pound, the average nett profit works out to As. 9-0 per pound. In the factory, if worked for 15 hours a day (two shifts), the total production in a year of 300 working days would be 7,80,000 pounds. Thus the profit being As. 9-0 per pound, the nett profit available for the shareholders works out to Rs. 4,28,750 per annum.

At an additional cost of about one lakh, the manufacturing plant for transparent viscose paper can be added. It is estimated that the rate of profit on this product will be more than double that on artificial silk.

The above estimates are based on the viscose process, which is the cheapest and most popular of all the processes described in this book. The acetate process has not been taken into consideration in arriving at the estimates, for the following reasons.

(1) The high cost of the raw material and chemicals.
(2) The difficulty in recovering the solvents.
(3) The considerable waste in the manufacturing process.
(4) The difficulties in connection with dyeing.

The other processes mentioned in this book are too complicated and costly to deserve any practical consideration here, and it is inconceivable that any Indian manufacturer would ever think of adopting any of them, whereas the viscose process has everything in its favour, as has been fully demonstrated. The acetate and other processes have been briefly described merely for the information of chemists and others who may be interested in the subject.

The machinery manufacturers supplying the machines would guarantee their efficient working. They

would work the machines themselves through their own experts for a year or more, till the Indian young men, whom they would thoroughly train during this period, were fit to take their place. So confident are the manufacturers of the certain success of the projected artificial silk industry in India, that they would be prepared to consider the question of coming to some satisfactory arrangement by which they would take shares in the company to be floated in part payment for the machinery supplied by them. This surely will reassure the intending investor, if indeed any further reassurance be still necessary.

Conclusion.

Under varying climatic conditions the other industrial countries of the world, not excluding even Spain and Brazil, have successfully manufactured artificial silk; but strange to say, a country like India, where it is consumed in very large quantities, where labour is cheap and learned in the art of weaving, where all the different necessary climatic conditions prevail, where all the raw materials employed in its manufacture are freely available, and in abundance, has not even attempted to manufacture it.

A careful perusal of the list of the countries that are manufacturing artificial silk will reveal the fact that they are far less blessed than India in these matters, and yet they are working it successfully, and there can be no reason whatever why India should not work it with equal or even greater success.

Artificial silk can be manufactured from sawdust, waste paper, cotton waste, rags, etc. All these are freely available in abundance in India and at a very cheap price. Cotton or cotton waste is the best material, as this is very rich in cellulose, from which artificial silk is prepared. The yarn manufactured from cotton is of

a stronger and finer quality than the yarn produced from other materials. In this country cotton is grown in abundance, and the surplus is exported to other countries, while it could be more profitably employed here in the manufacture of artificial silk. The present time, when we hear so much talk of the Japanese boycott of Indian cotton, would appear to be a particularly favourable period for utilising Indian cotton in this way.

All the necessary chemicals also are freely available in India. Labour conditions in India are far more favourable than in any other country in the world, especially in these days when unemployment is rampant. There are starving millions of people who do not know even two meals a day and who are anxious for work. It is therefore high time for India to make a start with this profitable industry. By doing so she would free herself to some extent from the languishing dependency on imports for her needs; she would to a great extent help the prosperity of the country by checking the outflow of money; she would give employment to her industrious population and so would largely loosen the shackles of unemployment; and the consequent lowering of the price of artificial silk would mean a saving to the people of India, many of whom would begin to use it where they do not use it now because it is entirely of foreign manufacture.

BIBLIOGRAPHY.

The Manufacture of Artificial Silk, by E. Wheeler.

Scientific Discoveries of the 19th Century.

The Review of the Trade of India, published by the Government of India.

Notes Concerning Artificial Silk, by the Ateliers Mecaniques de Courbevoie.

Conditions and Prospects of United Kingdom Trade in India, by T. M. Ainscough.

Old Trades and New Knowledge, by Sir William Bragg.

Les Soies Artificielles, by A. Chaplet.

British Association Report, 1922, by Irvine.

Chemistry and Industry, by U. Pomilio.

Matières Plastiques Soies Artificielles, by Clément et Rivière.

Manchester Guardian Artificial Silk Supplement, April 15th, 1926, by Lehner.

Times Artificial Silk Supplement, January 19th, 1929, by P. E. King.

Artificial Silk, translated by F. M. Rowe.

Chemistry and Industry, 1928, by H. R. S. Clotworthy.

Artificial Silk and Its Manufacture, by Foltzer. Translated by Woodhouse.

Report of the Economic and Financial Section of the League of Nations on the Artificial Silk Industry, 1927.

Publisher's Note.

I hereby desire to introduce to the reader the Association for the Development of Swadeshi Industries, Delhi, of which I have the honour of being the Honorary Secretary. This organisation is not a trade concern, but is national in its character, with the development of industries in India as its sole object. It accordingly makes extensive enquiry in all countries as to the prospects in India of different industries, and collects information for the benefit of any who may feel interested.

Not being out for profit, all its officers are honorary, and they are imbued with a spirit of service to the Motherland.

If you are interested in any particular industry, or if you are unemployed, do not hesitate to write to the Association, who will do their best to serve you in any and every way possible.

Hony. Secretary,

Association for the Development of Swadeshi Industries, Delhi.